Journal

WATER POLLUTION CONTROL FEDERATION

Special Features

Ground-Water Pollution Research—McKee

Lagoons in Wisconsin—Mackenthun and McNabb

Combined Sewer Overflows—Benjes et al.

Wastewater Treatment Standards—Ettinger

Thermal Pollution—Hoak

Milwaukee Meeting Report

1961 ANNUAL INDEX

Season's Greetings

DECEMBER 1961

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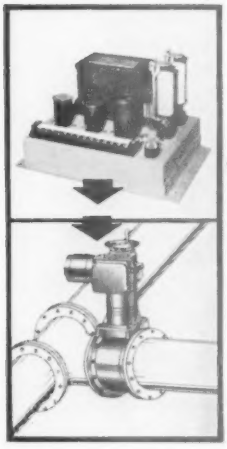

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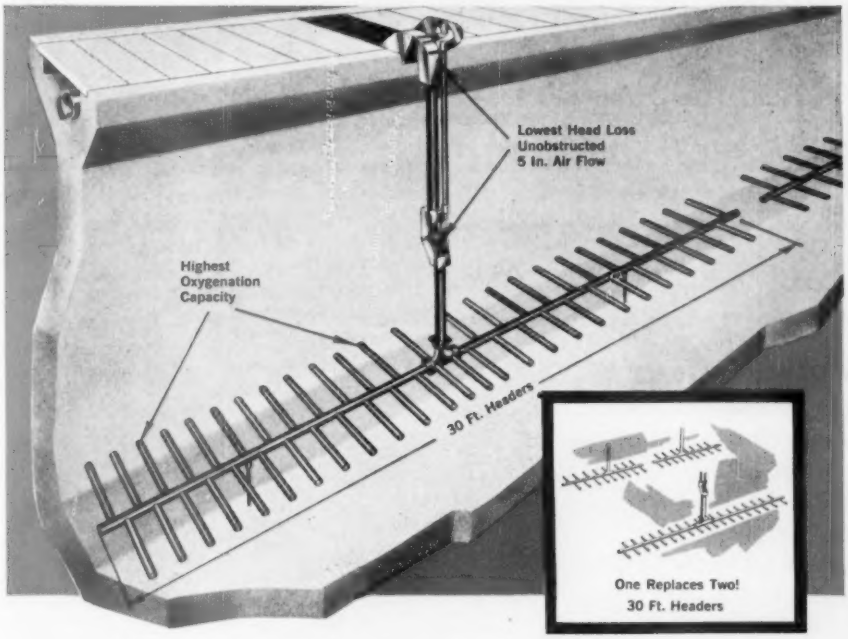

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Volume 33 | December 1961 | Number 12

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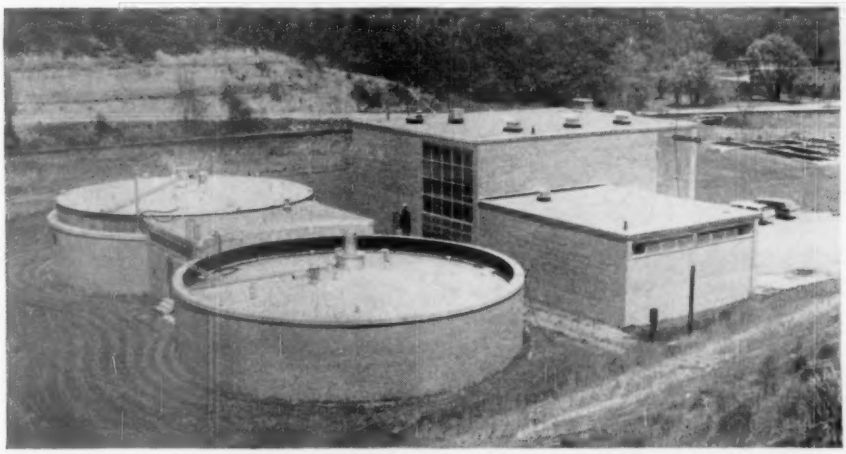

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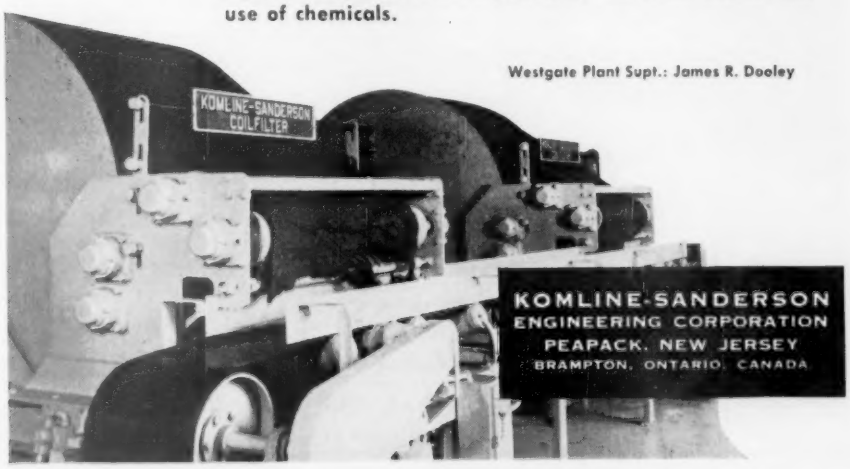

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Association *	*Date*	*Place*
Alaska	Jan. 11, 1962	Harbor House, Anchorage
New York	Jan. 17–19	Park Sheraton Hotel, New York
Mississippi	Mar. 7	Robert E. Lee Hotel, Jackson
Texas	Mar. 11–16	Texas A & M College, College Station
Louisiana	Mar. 14–16	Louisiana State University, Baton Rouge
Arkansas	Mar. 19–21	Marion Hotel, Little Rock
New Jersey	Mar. 28–30	Traymore Hotel, Atlantic City
Montana	Apr. 5–7	Baxter Hotel, Bozeman
Virginia	Apr. 9–10	Hotel Roanoke, Roanoke
West Virginia	Apr. 11–12	Hotel Morgan, Morgantown
California	Apr. 25–28	Sacramento Inn, Sacramento
Kansas	May 2–4	Lassen Hotel, Wichita
Arizona	May 3–5	Pioneer Hotel, Tucson
Michigan	May 21–23	Park Place Hotel, Traverse City
Alabama	June 4–6	Auburn University, Auburn
New England	June 6–7	Wentworth by Sea, Portsmouth, N. H.
Iowa	June 13–15	Hotel Hanford, Mason City
Central States	June 20–22	Hotel Duluth, Duluth, Minn.

* See preceding left-hand page for full name.

THIRTY-FIFTH ANNUAL MEETING

Water Pollution Control Federation

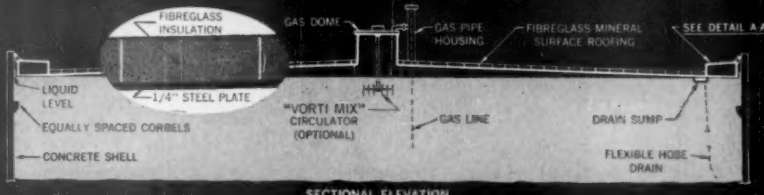
HOST—Canadian Institute on Pollution Control

Toronto, Ontario, Canada

Royal York Hotel

October 7–11, 1962

New MONODECK* floating cover



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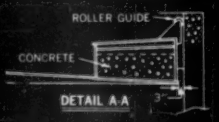

DETAIL A-A

cuts costs—incorporates improved structural and operating features

By exclusive arrangement with General American Transportation Corporation, INFILCO offers the "MONODECK" floating cover for sludge digesters in a full range of sizes. This cover, designed by Wiggins, offers the same basic structural features which have been incorporated in the 214 foot diameter gas holder for the City of Long Beach, California. The essential features and advantages of the "MONODECK" type cover are:

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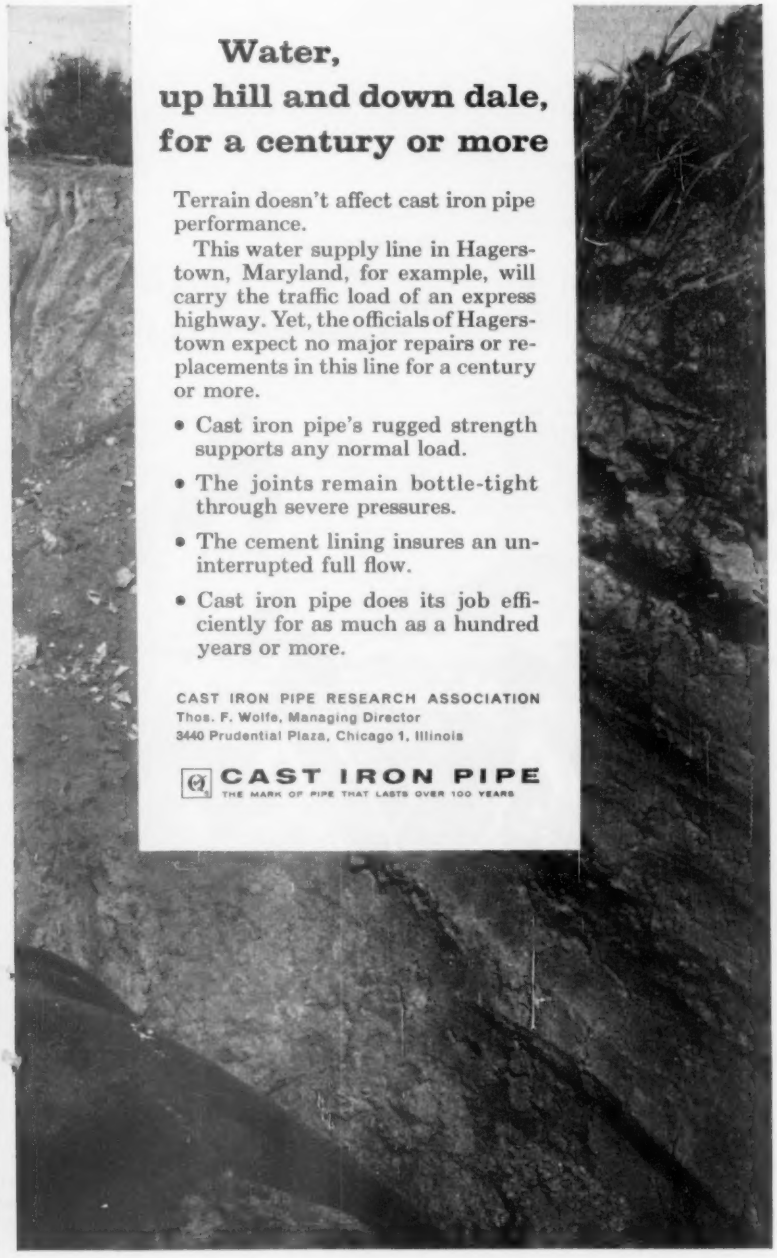

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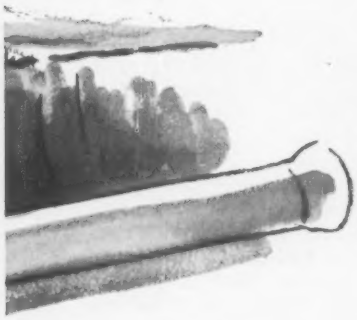

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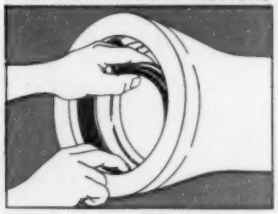
Makers of USIFLEX® Boltless Flexible Joint Pipe.

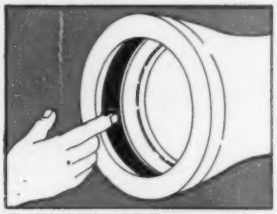
INDUSTRIAL SERVICE

TYTON®

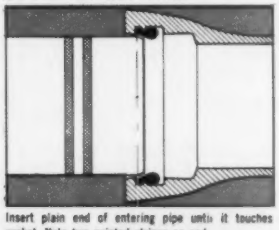
ONLY FOUR SIMPLE ACTIONS



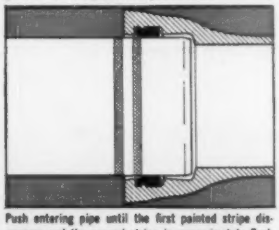
Insert gasket with groove over bead in gasket seat . . . a simple hand operation.



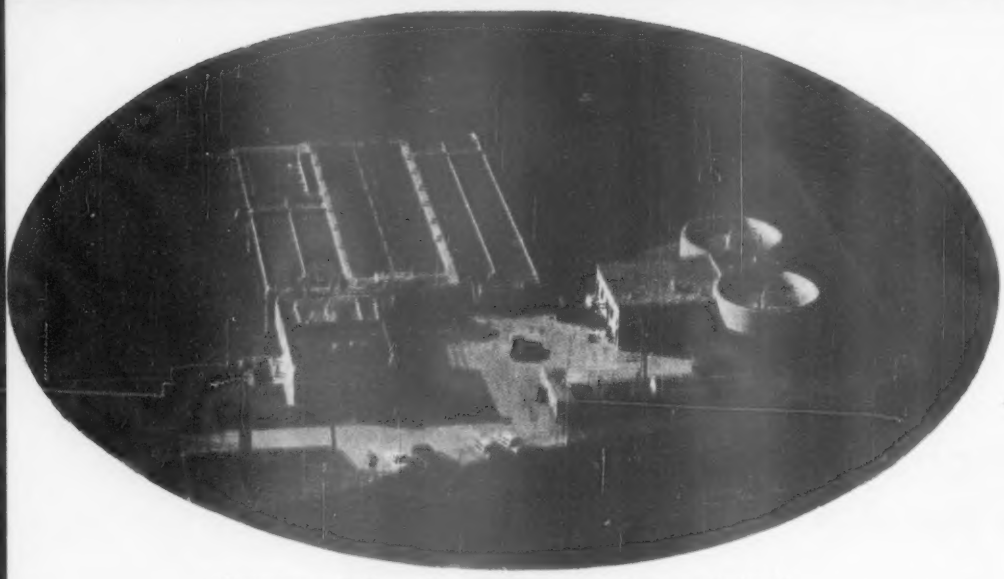
Wipe film of Tyton Joint® lubricant over inside of gasket. Your receiving pipe is ready.



Insert plain end of entering pipe until it touches gasket. Note two painted stripes on end.



Push entering pipe until the first painted stripe disappears and the second stripe is approximately flush with bell face. The joint is sealed . . . bottle-tight, permanently! The job's done . . . fast, efficiently, economically. Could anything be simpler?



Logansport, Indiana, Sewage Treatment plant was designed by Henry B. Steeg and Associates, Indianapolis, Indiana.

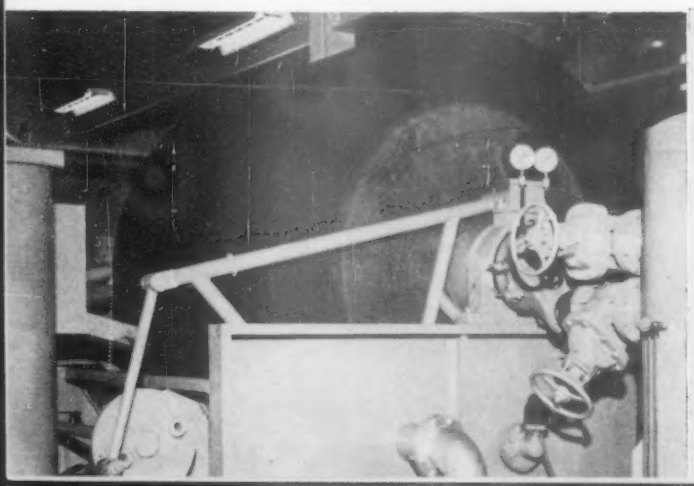
Cake Moistures Average 68.8% with EIMCOBELT® Filter at Logansport, Ind.

Low cake moisture is only one of several ways this EimcoBelt continuous belt filter results in low costs dewatering a primary activated digested sludge at the Logansport, Indiana, Sewage Treatment plant.

Other cost-cutting advantages of the 8-ft. diameter by 6-ft. EimcoBelt filter — complete freedom from filter medium blinding . . . high vacuums . . . low chemicals costs . . . ability to discharge thin cakes . . . negligible maintenance. Sludge dewatering costs at Logansport—$9.80 per ton of dry cake.

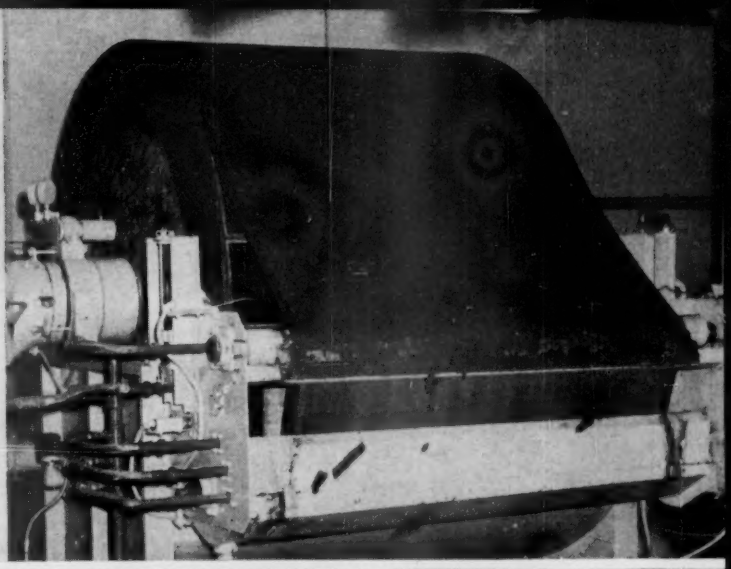
In dozens of other sewage treatment plants, too, EimcoBelt filters are setting new, high operating records, dewatering all types of sewage sludge.

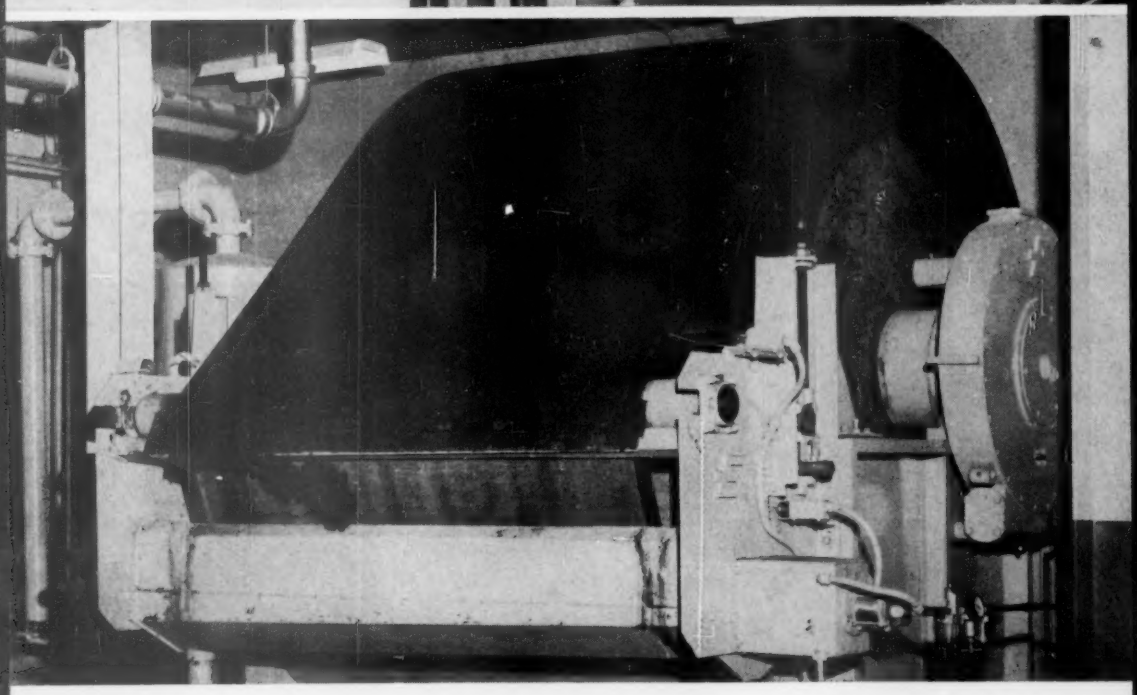
The Eimco representative in your area will be glad to sit down with you and your consultants and provide specific facts on how EimcoBelt filters can reduce costs in your plant. Call him, and write The Eimco Corporation, Filter Division, Salt Lake City 10, Utah, U.S.A. for Bulletin FJ-2053.



Hy-Flow filter valve, developed by Eimco, eliminates all right angle bends in passages, resulting in the most effective use of vacuum.

High vacuum levels of 20-26-in. Hg. can be maintained across the face of the drum on EimcoBelt filters. Improved seal eliminates end leakage.





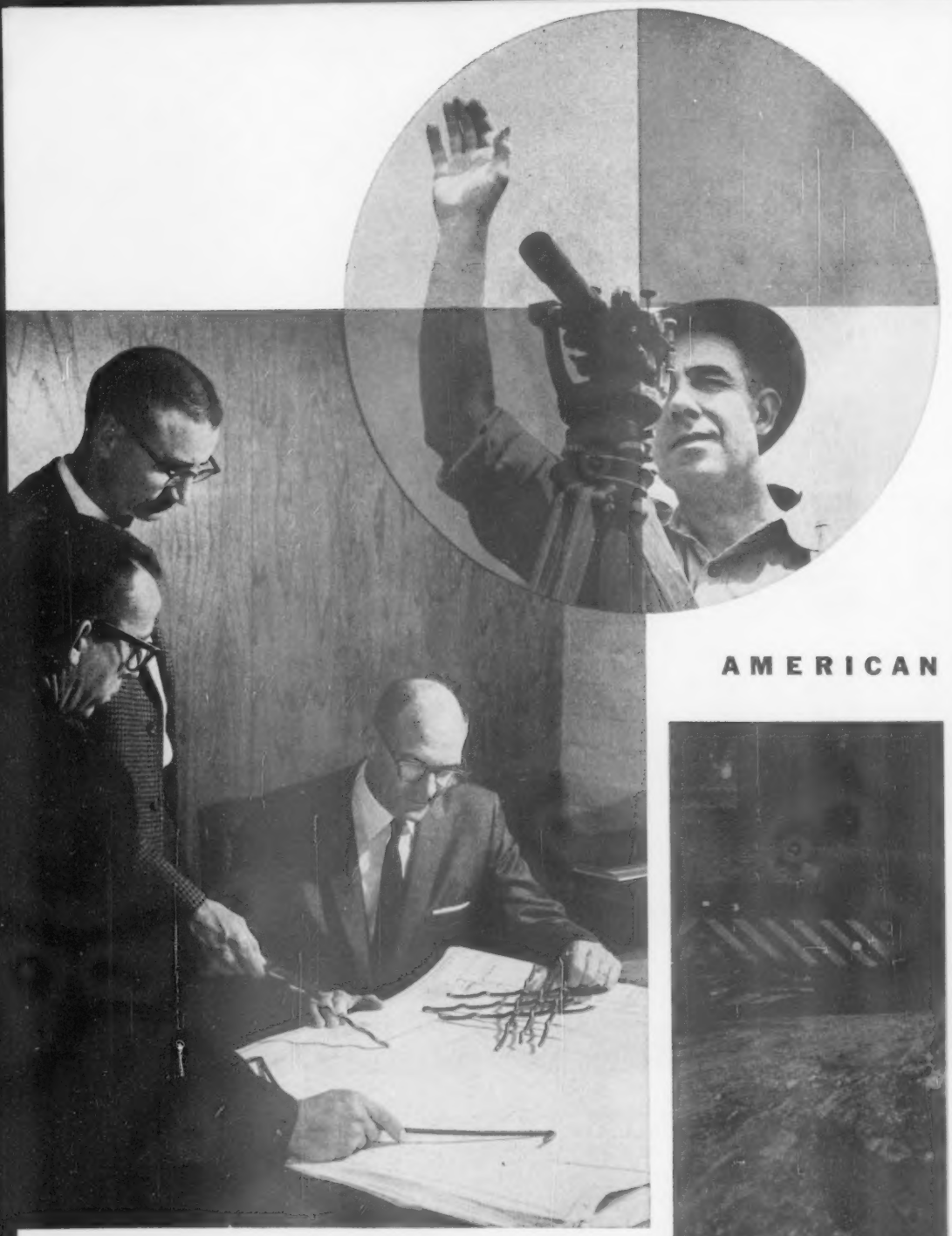
EimcoBelt filters remove the belt filter medium from the drum continuously for cake discharge and cleaning. High velocity sprays wash the medium clean, front and back, before it is returned to the drum. No fall-off in filtration rate caused by progressive blinding.

EimcoBelt and Hy-Flow are trademarks of the Eimco Corporation.

EIMCO

"Advanced Engineering and Quality Craftsmanship Since 1884"

B-738A



AMERICAN

First and last it pays to make concrete plans for your community with the best possible medium for water transmission—CONCRETE PRESSURE PIPE.

Your community's future demands concrete planning

Why are so many communities turning to concrete pressure pipe for their main water lifeline of the future? Farsighted waterworks authorities recognize that the present critical demands, brought about by our recent population and industrial explosion, may easily be doubled within the next 25 years.

They also recognize that, with concrete pressure pipe, plans for the future are laid on a solid foundation of an exceptional life span, minimum maintenance requirements and virtually no replacement costs. But most of all, their planning can be accurate, because concrete pressure pipe's initial high carrying capacity will remain unimpaired in years to come when demands on the line will be highest.

WATER FOR GENERATIONS TO COME

Concrete PRESSURE Pipe

CONCRETE PRESSURE PIPE ASSOCIATION

228 North LaSalle Street • Chicago 1, Illinois

FLEXICROME

90% of the Cities in the United States use this ROD for cleaning sewers . . .

THERE MUST BE A REASON!

- BEST BY LABORATORY AND FIELD TEST
- SPECIAL STEEL FOR SEWER RODDING
- ACID RESISTANCE TREATED
- GROOVED COUPLINGS

FLEXICROME RODS are the end result of many years of field and laboratory tests. When you specify **"Flexicrome"** you get these important, exclusive features:

* **Special alloy steel for extra toughness and durability.**
* **Heat fused rod coating for better sewer acid resistance.**
* **Solid center, grooved couplings for extra rod end support, and faster assembly.**

Patent No. 2,471,060

FLEXIBLE INC.

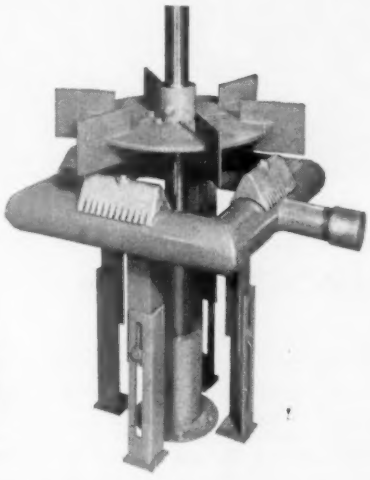
3786 Durango Ave. • Los Angeles 34, Calif.
LIMA, OHIO DALLAS, TEXAS

NEW AMERICAN MECHANICOMB TOTAL OXIDATOR-AERATOR

This 4-in-1 "Mechanicomb is a diffusion aerator, mechanical aerator, and agitator all-in-one—utilizes sparged air and atmospheric air—achieves total oxidation through complete aeration-mixing, constant agitation, and continuous diffusion. Combines the American Aircomb Diffuser with the American Mechanical Aerator and Turbine-Type Impellers. Facilitates and accelerates the treatment of sewage and industrial wastes.

As it introduces and distributes air at the desired rate, the Mechanicomb keeps the tank contents in violent and intimate contact with this air to assure the greatest amount of oxygen absorption and aeration mixing. Does not permit any settling at the bottom of the tank—greatly increases oxidation efficiency.

Send for Bulletin No. 420



ALL-IN-ONE
Diffusion Aerator
Mechanical Aerator
Continuous Agitator
Utilizes both Sparged Air and Atmospheric Air

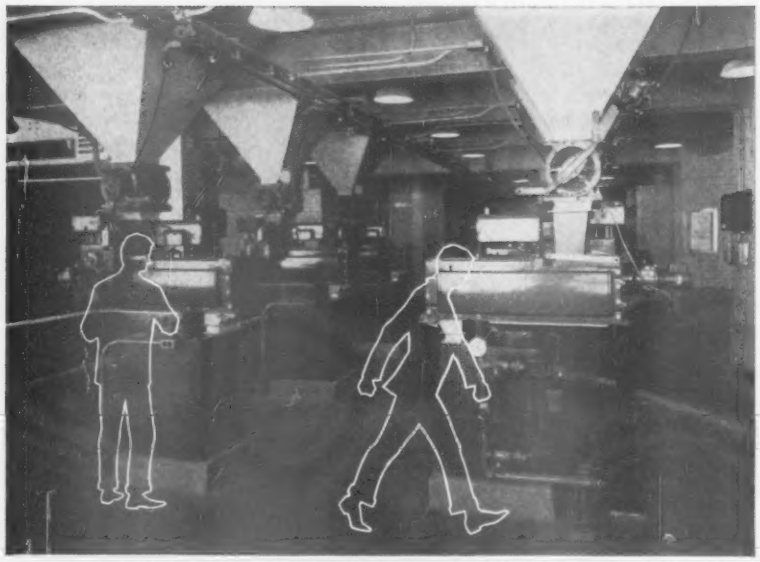
UNIQUE AIRCOMB® DIFFUSER

Teeth on both sides provide multiple, variable-capacity, self-cleaning orifices that automatically adjust the air-flow for controlled aeration. Peak-dome design prevents accumulation of solids. Used in variety of arrangements, as in the Mechanicomb shown above, or in parallel on header pipes. No maintenance is required. Guaranteed unconditionally for five years.

Send for Bulletin No. 415. (Patent No. 2,917,295)

The complete AMERICAN line includes a wide selection of methods, processes and equipment for sewage treatment, industrial waste treatment, and water purification. Consult our engineering staff for expert application aid and technical data.

AMERICAN WELL WORKS
110 N. BROADWAY AURORA, ILLINOIS
Research, Engineering and Manufacturing — AMERICAN EST. 1868 — Waste and Water Treating, Mixing, and Pumping Equipment
SALES OFFICES: CHICAGO, NEW YORK, AND OTHER PRINCIPAL CITIES



SET IT . . . FORGET IT . . .

THE W&T MERCHEN FEEDER

When your dry feeding process calls for accuracy hour after hour, you need Merchen Feeders. Wallace & Tiernan Merchens feed like clockwork without attention . . . never waver in even the most exacting use.

Their 0.1% sensitivity means that a change as small as 1 ounce in a 63-pound belt load automatically corrects the feed gate setting. You get continuous delivery at set feed rate. And you get true gravimetric feeding. Merchens are never affected by density changes. They self-adjust. You select the feed rate; the Merchen does the rest.

And Merchens give you the other qualities you look for in a feeder: minute-to-minute accuracy within ±1%, rigid, vibration-free construction, compact size to fit almost anywhere.

For more information, write Dept. M-63.84.

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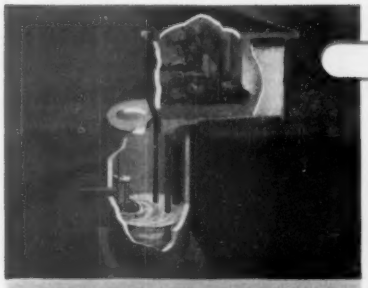
Davco

SPECIALIZED EQUIPMENT

FOR WATER AND SEWER INDUSTRY

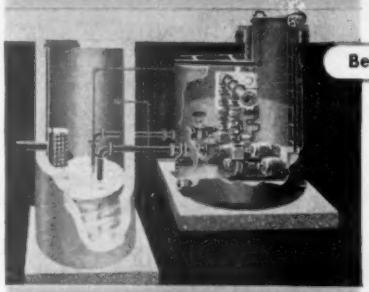


ECONOMICAL

Above Ground Sewage Lift Station

- Lower Purchase and Maintenance cost
- Maintenance Ease
- Most accessible impeller on the market
- Exclusive Davco non-clog self priming sewage pump.

Davco Only Davco offers a complete line of sewage lift stations.

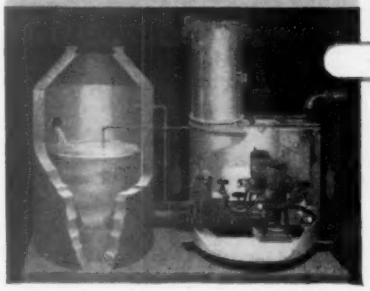


DEPENDABLE

Below Ground Self-Priming Pump Station

- Flexible bulkhead seals or grouted sleeve
- Automatic, time tested controls system.
- Positive high lift self priming pumps.
- Lifelong exterior protection

Davco Davco planning and design service available to consulting engineers.



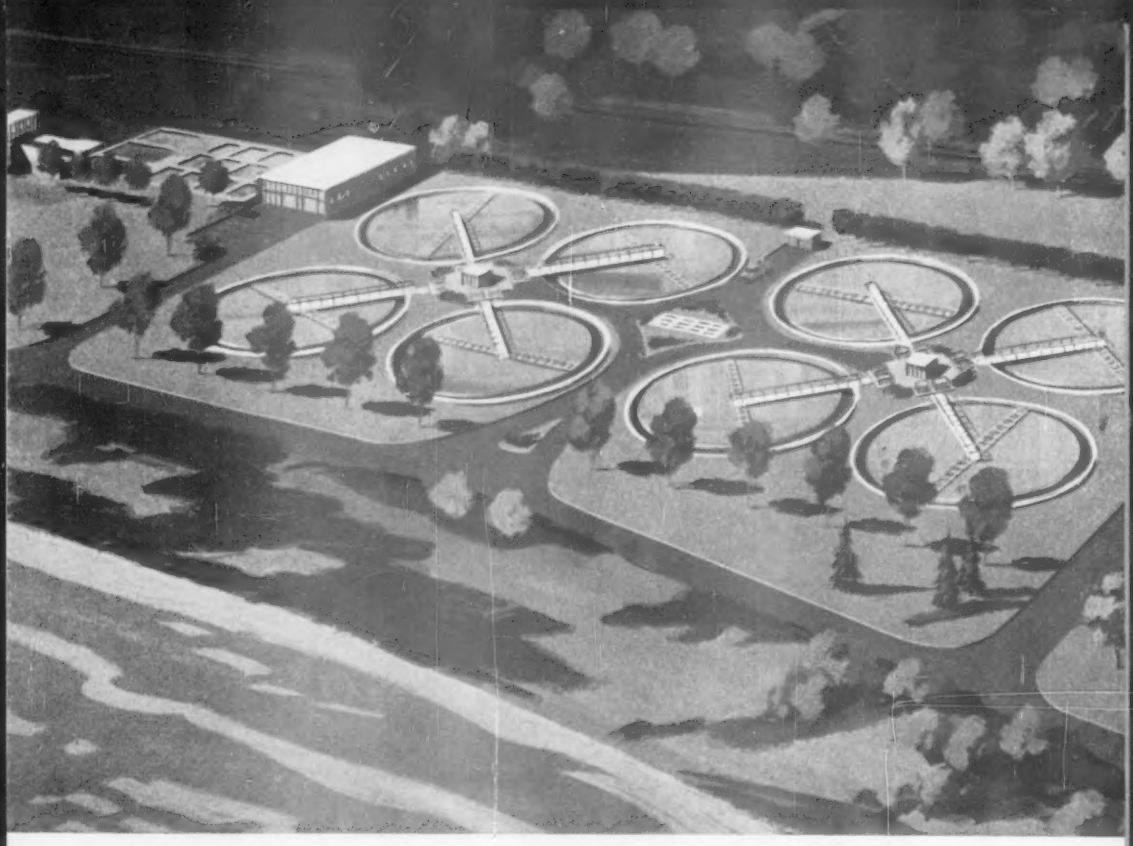
Flooded Suction Sewage Lift Station

- Flexible Bulkhead Seals or grouted sleeve.
- Flood Control Devices
- Automatic, trouble free control system
- Lasting service.

Write today for complete details and specifications

Davco CORPORATION

P. O. BOX 270 THOMASVILLE, GEORGIA CA 6-6458



New $9 million sewage features C-E Raymond Flash

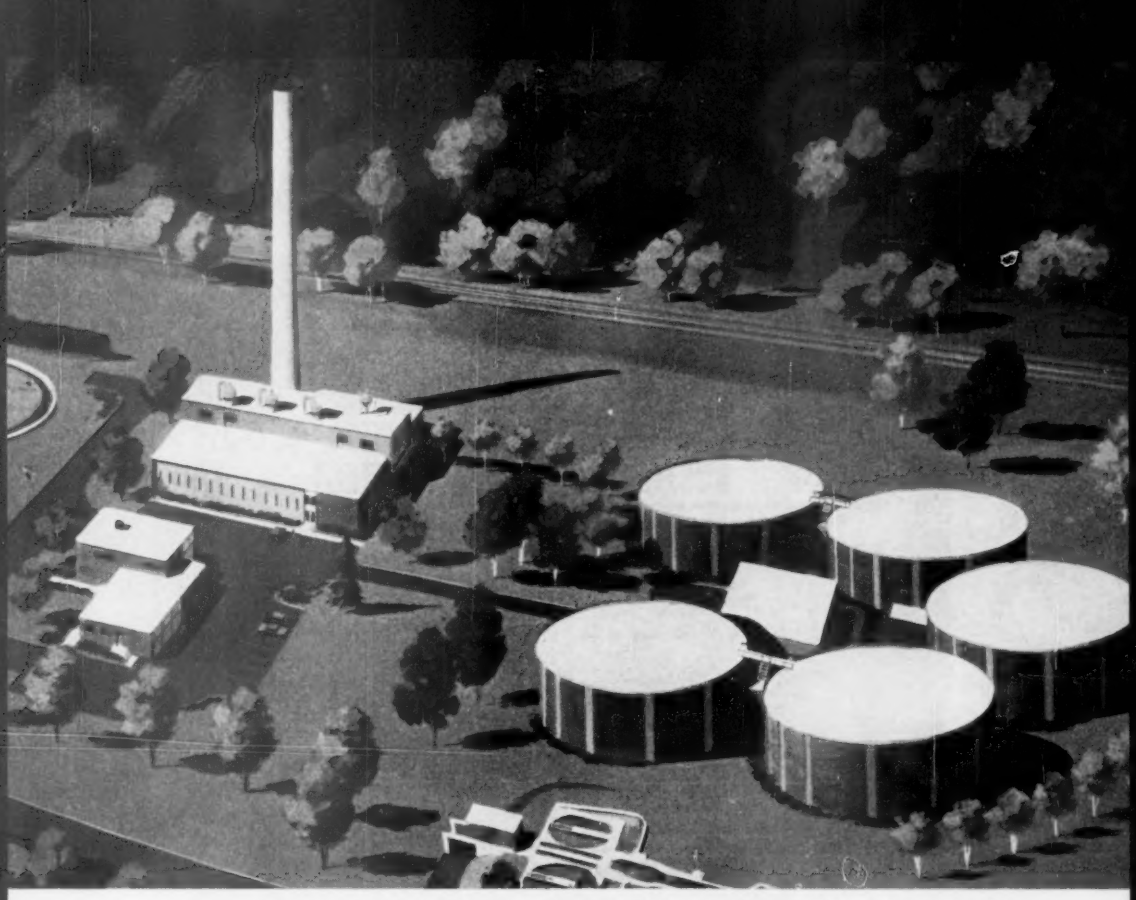
Omaha selects C-E Raymond for second major installation

The City of Omaha recently ordered three C-E Raymond Incinerator Units for installation at its new Missouri River Sewage Treatment Plant now under construction. Henningson, Durham & Richardson are the Corsulting Engineers.

This plant will serve an equivalent population of 2,000,000 and will have a dry weather flow of 70 mgd, and an influent capacity of 210 mgd. Treatment will be on a primary digested basis, but the C-E Raymond equipment is designed to incinerate either raw primary or digested primary sludge. The sludge will be burned to a sterile, clinker-free ash, but the plant will be equipped so that the solids from any one of the three C-E Raymond units can be dried for sale as a soil conditioner of low and uniform moisture content. This is the *only* system that permits both drying and incineration—separately or together—in any proportion.

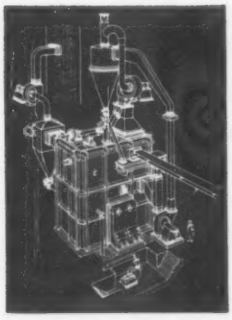
This is the second Omaha plant for which C-E Raymond equipment has been chosen. The first plant, the 12-mgd Papillion Creek treatment plant, for which Henningson, Durham & Richardson were also consultants, has been in operation since 1959. This plant, containing a C-E Raymond Sludge Incinerator System proved the efficiency and economy of this equipment.

Our specialists will be glad to discuss with you or your consultants the many benefits this system can provide your community. For full information contact the C-E office nearest you.



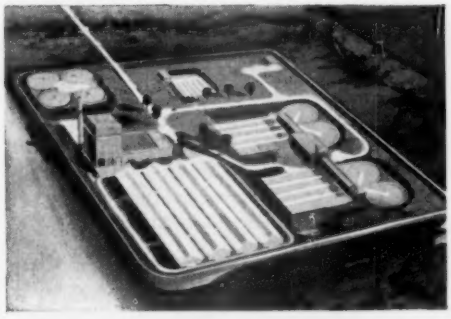
Hawkins-Tolboe-Harlin (a Joint Venture), Omaha, Nebraska, are General Contractors for Omaha's new $9-million Missouri River Sewage Treatment Plant, architects rendering of which is shown above.

treatment plant for Omaha Drying and Incineration System



Right: Omaha's Papillion Creek treatment plant where C-E Raymond sludge disposal equipment has provided controlled drying, efficient incineration and excellent fly ash control since 1959. The Parsons Construction Company was the General Contractor.

Left: The C-E Raymond Flash Drying and Incinerator System provides maximum efficiency in processing filter cake — permits both drying and incineration, simultaneously or separately, in any proportion.



COMBUSTION ENGINEERING

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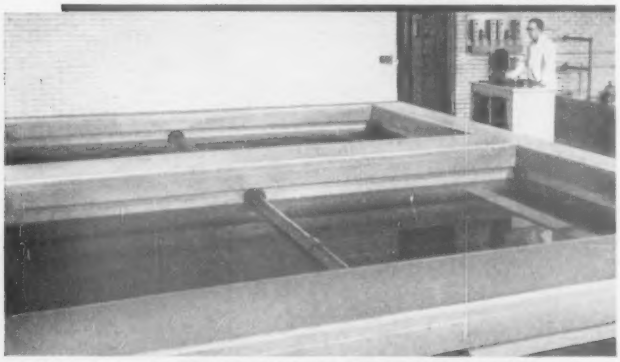
PAPER MILL EQUIPMENT; PULVERIZERS; FLASH DRYING SYSTEMS; PRESSURE VESSELS

SOUTH HAVEN, MICHIGAN

SEWAGE WORKS — **25 YEARS LATER, 95% PERFECT... SUBMERGED INERTOL® STANDARD PAINT**

WATER WORKS — **6-8 YEARS WITHOUT REPAINTING ...SUBMERGED TOREX® ENAMEL**



WATER WORKS Interior view of the South Haven Water Works with Mr. Clair B. Mills, operator at the control panel where he is washing filter. Filters are protected and beautified with Torex Enamel.

SEWAGE WORKS Exterior of the South Haven Pollution Control Plant where the submerged areas of the Imhoff tanks are painted with Inertol Standard. Adjusting tank valves is Mr. Everett Hattabaugh, supervisor and chemist.

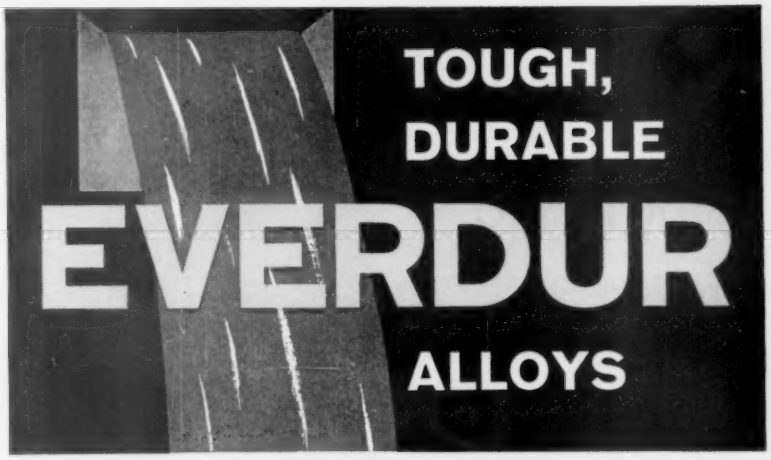
The city of South Haven is pleased with Inertol Standard in its sewage plant. Over 25 years ago two coats were applied to Imhoff tank interiors. "Today," says Mr. Max L. Norris, superintendent, "the overall paint job is still in 95% good condition; it is practically perfect on submerged surfaces not subject to tank level fluctuation."

In the South Haven water works, colorful Torex Enamel protects filter walls. "Despite the continued submersion," reports Mr. Norris, "the filters are only repainted with Torex every 6-8 years. Just one coat is required for repainting."

For further data on Torex Enamel, write for Bulletin WS579; on Inertol Standard (for sewage plants only), Bulletin SW594.

A complete line of quality coatings for water, sewage and industrial wastes plants, and swimming pools.

INERTOL CO., INC.
482 Frelinghuysen Avenue, Newark 12, N. J.
27-H South Park, San Francisco 7, Cal.



highly resistant to wear and abrasion in sewage and water works systems

EVERDUR® copper-silicon alloys have excellent resistance to corrosion in all types of water works installations and at all stages of sewage treatment operations. EVERDUR equipment in the United States has been in service *without replacement* for 30 years and longer.

Easily fabricated EVERDUR provides high physical strength with lighter weight. It is used extensively in sewage systems handling corrosive wastes in screens, stems, manhole steps, guides, bolts, weirs, float chambers, troughs. And for water works equipment you will find EVERDUR alloys in long service as surface reservoir outlet screens and screen frames and as large diameter cylindrical well screens in drilled well supply systems. Other uses: spillway fittings, guides, seats and sealing strips. And don't forget EVERDUR Electrical Conduit for use in corrosive atmospheres.

Publication E-11 shows typical applications and other data. Write for your copy—or for assistance from our Metallurgical Dept. in selecting the proper corrosion-resistant alloys for your equipment. Address: Anaconda American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Canada. 61-811

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a product of
ANACONDA®
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Steel

Strong,
Durable,
Economical

Armco
SMOOTH-FLO
Provides
Top Flow
Capacity,
Long
Service Life

New steels are born at Armco

Armco SMOOTH-FLO® Sewer Pipe – corrugated galvanized steel with a smooth, centrifugally-applied bituminous lining that completely fills the inside corrugations – combines top flow characteristics with strength *and* abrasion resistance. For severe corrosive or flow conditions, lining and coating are bonded to the base metal by asbestos fibers.

SMOOTH-FLO Structures, available in a wide range of lengths, gages and diameters, are flexible. They withstand heavy loads and shock without cracking, breaking or disjointing. Joints are watertight and defy separation by roots and frost action.

See how Armco SMOOTH-FLO can meet your design requirements. Write **Armco Drainage & Metal Products, Inc., subsidiary of Armco Steel Corporation, 6651 Curtis Street, Middletown, Ohio.**

ARMCO Drainage & Metal Products

These valves last when others are lost

HOMESTEAD® LUBRICATED PLUG VALVES

They keep right on working when ordinary valves have to be replaced. Why? For several reasons. First, because of very close tolerances between sealing surfaces of the plug and body (.002″ clearance on small sizes, and .005″ to .007″ on the largest sizes). Second, because of their *controlled* pressurized lubrication system which guarantees complete coverage of all sealing surfaces, provides chemical seal against leakage and protection against corrosion. Add to these the positive plug-freeing action which occurs with each lubrication, and it's easy to see why Homestead Lubricated Valves last. Get the complete story. Send for Reference Book 39-1; and for the assurance that quality brings, specify Homestead Lubricated Plug Valves.

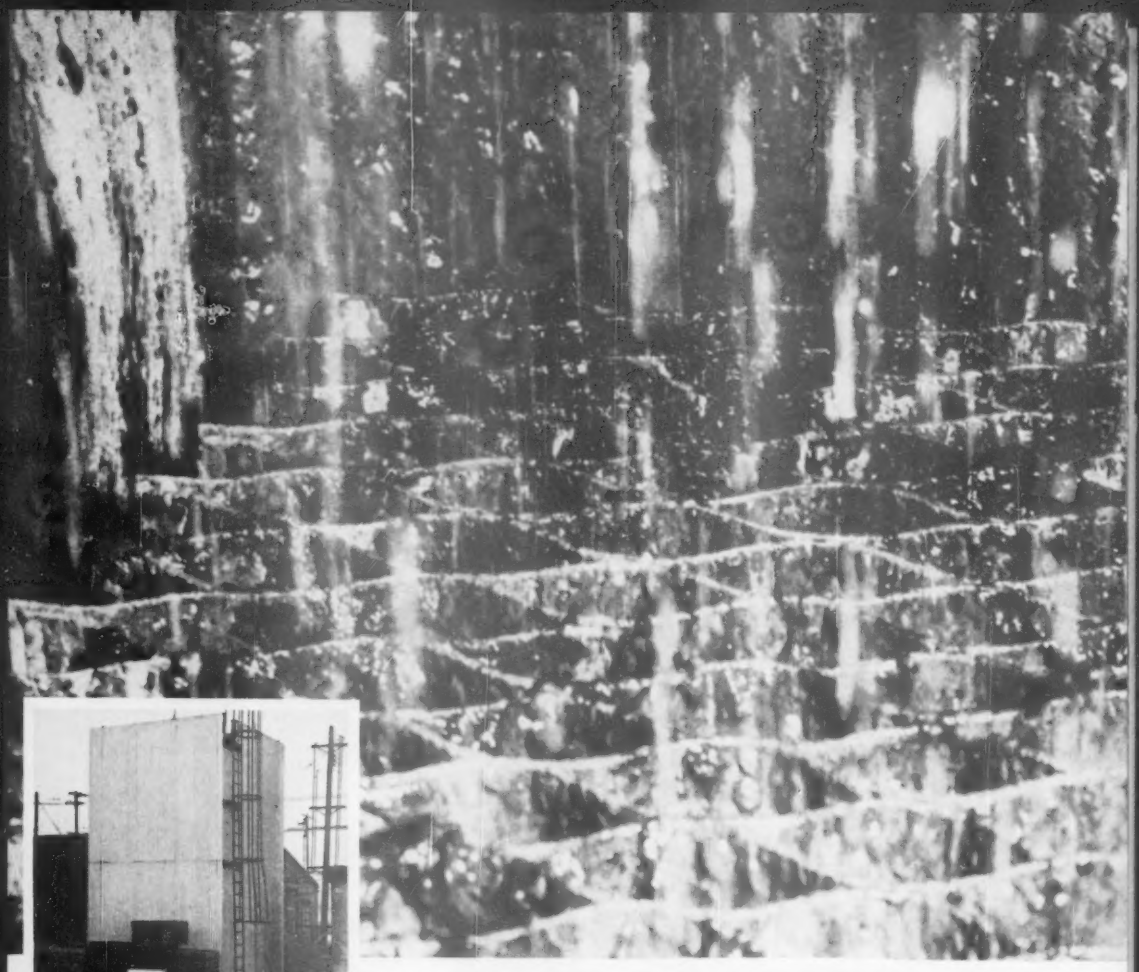
hv

HOMESTEAD VALVE MANUFACTURING COMPANY

"Serving since 1892"

P. O. Box 48, Coraopolis, Pennsylvania

Makers of: Homestead Ball Valves, Cam-Seald, Lever-Seald and Lubricated Plug Valves.



Dowpac provides tremendous surface area in a small volume of space, it weighs little, and tower maintenance costs are negligible.

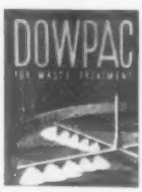
NEW DOWPAC MEDIA TREAT SEWAGE AND WASTE FAST IN LITTLE SPACE

. . . D.I.S. offers low-cost pilot plant to prove system for your waste conditions!

Contoured plastic sheets of Dowpac® packing media interlock (above) to form a continuous, lightweight grid for low-cost treatment of water-borne wastes. Because of light weight and high operating efficiency, a waste treatment system using Dowpac requires much less land area for construction than other waste systems, while operating at higher waste concentrations.

Cost advantages—Economical first cost . . . low maintenance and operating costs . . . conserves expensive land. **Operating advantages**—large area for bacterial growth . . . efficient aeration . . . freedom from plugging. **Total advantages**—a D.I.S. waste treatment system using Dowpac costs you less to install and operate and treats more waste faster, at higher concentrations, than other kinds of systems.

Pilot plants employing Dowpac can be rented or purchased, and D.I.S. engineers will help customers develop the most effective use of Dowpac for their particular waste conditions. Dow Industrial Service works with industries of every kind, anywhere in the U. S. Further, D.I.S. offers consulting laboratory service for water and waste treatment, backed by technical resources of THE DOW CHEMICAL COMPANY. For further information, write or call DOW INDUSTRIAL SERVICE, 20575 Center Ridge Road, Cleveland 16, O., Dept. JWPCF12.



FREE BOOKLET on low-cost, high efficiency waste treatment using Dowpac. Send for a copy today.

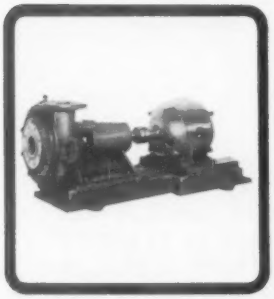
DOW

Dowpac is a trademark for packing media—not pilot plants

DOW INDUSTRIAL SERVICE • Division of The Dow Chemical Company

PERFORMANCE-PROVED

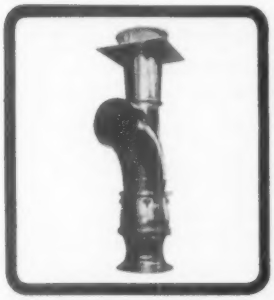
Trouble-free years of operation without replacement of major parts, with only routine maintenance, isn't just a claim—C. H. Wheeler pumps are 40 years' performance-proved on the job. (Pumps having higher capacities than those illustrated are available.)



HORIZONTAL NON-CLOG PUMPS. Sewage disposal plants prefer these units for unscreened liquids, sewage. Non-clog impeller, ball bearings, renewable shock absorber. Sizes: 3″—24″. Capacities: 40-5000 gpm. Heads to 160 ft.

VERTICAL NON-CLOG PUMPS in Open-Shaft and Sentry types for dry pit installations. Many engineering advancements bring higher pump efficiency, lower maintenance costs. Service, performance data and sizes same as Horizontal Non-Clog Pumps.

VOLUTE PUMPS OF MIXED FLOW OR NON-CLOG DESIGN are ideal for many pumping applications including: screened sewage, for drainage, irrigation, flood control and industrial water supply. Horizontal and vertical designs available. Sizes: 12″—48″. Capacities: 3000-100,000 gpm.



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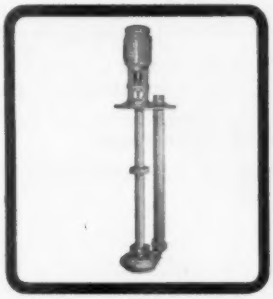

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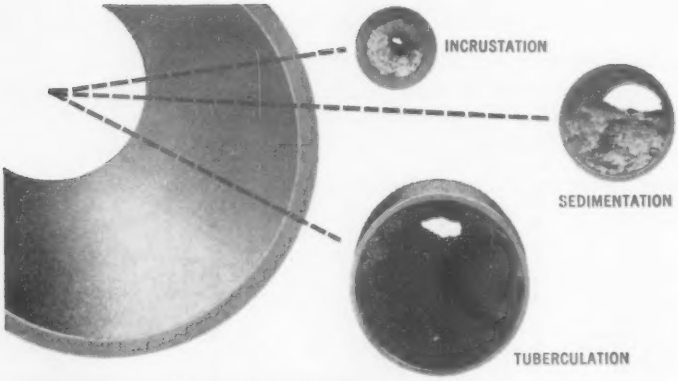

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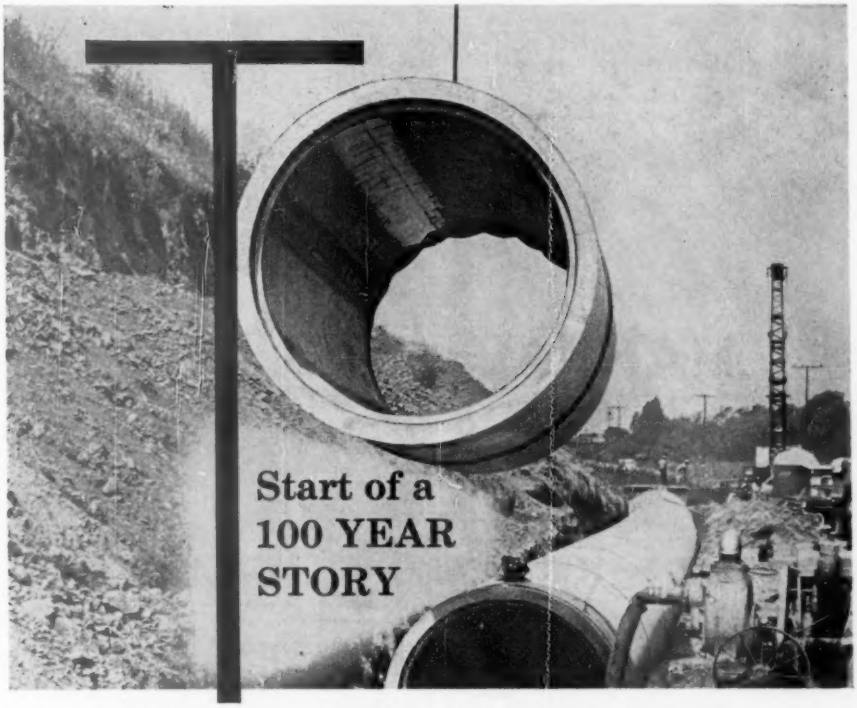

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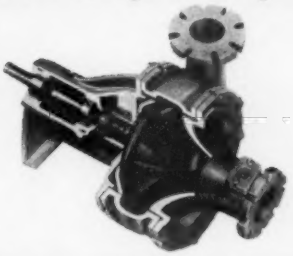

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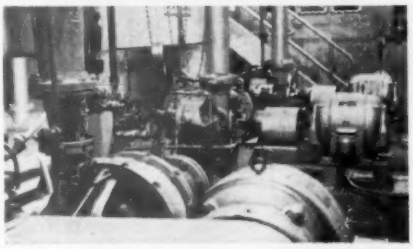

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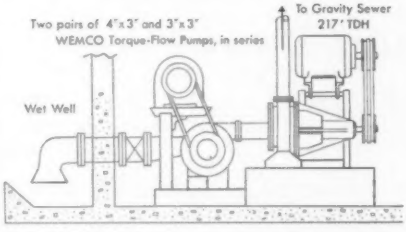

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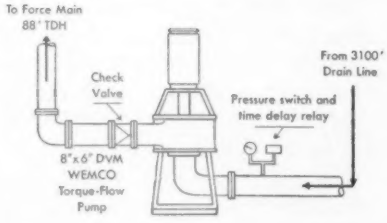

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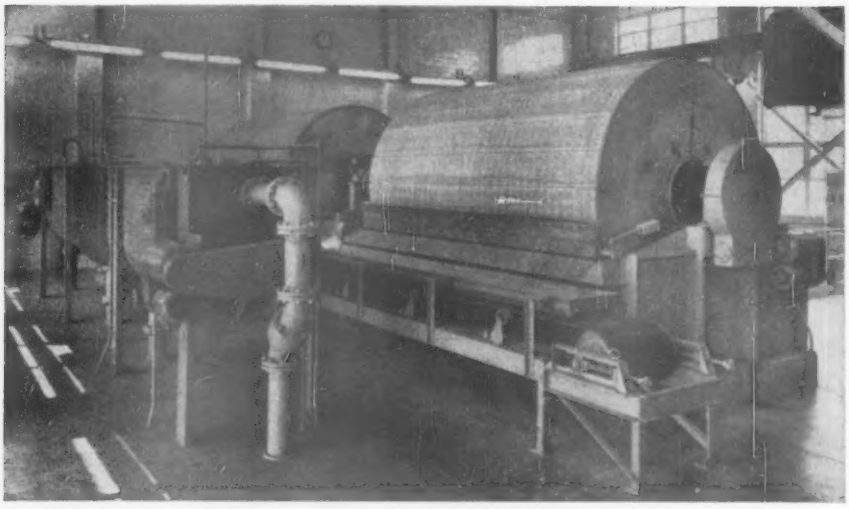

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RESEARCH NEEDS IN GROUND-WATER POLLUTION

J. E. McKee

This paper is not a review of all research that has been performed or is currently being undertaken in relation to ground-water pollution. Instead, it is an attempt to categorize the major areas of research that should be pursued in order to increase the knowledge of this relatively untouched field. Some of the research ideas listed here may have been tackled already, but more research along parallel or corollary lines is still needed. There is much to be learned about this subject.

Categories of Research Needs

Insofar as scientific disciplines are involved, the research needs in ground-water pollution may be classified into the following major groups: (*a*) chemical, (*b*) physical, (*c*) biological, (*d*) geological, and (*e*) mathematical. There are, to be sure, many problems that involve more than one scientific discipline, or a combination of them, such as biochemistry, geochemistry, physical chemistry, and radiochemistry. Mathematical techniques may be used in each category. Geohydrology, a study of the occurrence and behavior of water in the ground, embraces all of these areas.

Supplementing the problems related to scientific disciplines are those that involve administrative considerations and judicial expression. Beyond any doubt there is need for a clearer understanding of the control of ground water. Furthermore, engineers, scientists, waterworks officials, industrial representatives, and many others will welcome a definitive pattern of legal opinion relative to ground-water pollution. It is not within the purview of this paper, however, to describe the ground-water research needs in the fields of administration and law other than to recognize that they exist and that they are important. Instead, the following discussion will be limited to the five scientific categories listed above, their combinations, and their subcategories. Finally, there will be a brief comment about the greatest need of all in ground-water research today.

Chemical Problems

By far the most numerous and complex problems of ground-water pollution are those involving chemical phenomena.

There is a need to know more about the chemistry of various types of soil, for this medium is seldom inert. Indeed, the chemical content of water flowing through an aquifer is dependent to a large extent on the adsorptive, desorptive, and exchange capacity of the soil. Soil chemistry is an advanced science, but most of the effort to date has been in the realm of agriculture. Notable have been the research and publications of the staff of the U. S. Department of Agriculture Salinity Laboratory at Riverside, California. Geohydrologists need to "bone up" on the work of the soil chemists and use

The paper was presented at the Public Health Service Symposium on Ground Water Contamination at Cincinnati, Ohio, Apr. 7, 1961.

J. E. McKee is Professor of Engineering in Environmental Health, W. M. Keck Laboratory of Environmental Health Engineering, California Institute of Technology, Pasadena, Calif.

the knowledge of this discipline to predict the effects of soil on the quality of water passing through it. Most of the work to date has been concerned with soil chemistry and water quality in the plant root zone, but many of the principles can be transposed to deeper percolating waters and confined aquifers.

Geologists classify soil in terms of its mineral analysis: e.g., percentage of mica, silica, dolomite, clay, etc. It would be useful if these mineral analyses could be transposed readily into chemical data from which the reactive characteristics of the soil could be utilized quantitatively.

Corollary to the area of soil chemistry is the need for improved and standardized methods for analyzing the adsorptive, desorptive, ion-exchange capacities, and redox potentials of various soils and the kinetics associated therewith. A field kit utilizing a little black box would be ideal for such analyses, but until it is available these phenomena can only be measured approximately by *in situ* observations with field wells, or by percolation through soil columns in the laboratory.

To be more specific, there is a need to know the rates of adsorption, desorption, and ion-exchange for each chemical substance and combination of chemicals in aqueous solution passing through specific types of soil. To what extent, for example, will iron and/or manganese be leached from a certain aquifer by distilled water or by waters of various mineral composition? What will be the effect of dissolved oxygen, carbon dioxide, methane, hydrogen sulfide, and other gases? What is the relation of the ORP to these reactions?

Can the extent be predicted to which calcium and/or magnesium will be exchanged with sodium and/or potassium as water of a known chemical composition passes through an aquifer of known permeability and mineral analysis, but unknown chemical properties? Kaufman (1) presented some data on ion-exchange softening in the South Coastal Basin at Los Angeles. More of this type of data is needed. What will happen to hexavalent chromates, borates, fluorides, phosphates, cesium, strontium, and other mineral ions in relation to various soils? Which ions are likely to be permanently adsorbed and which are likely to be eluted by a subsequent flow? Indeed, the entire subject of chromatographic effects in ground-water behavior is a relatively unexplored field. Without a doubt many soils act as a chromatographic column with respect to the substances in certain waters, but very little is known about this phenomenon.

Nitrogen and Sulfur Compounds

Two groups of mineral ions conspicuous by their omission from the foregoing paragraph are the inorganic nitrogen compounds; namely ammonia, nitrites, nitrates, and nitrogen gas, and the sulfur compounds; specifically sulfates, elemental sulfur, and sulfides. They deserve special consideration for they are subject readily to oxidation or reduction. What happens to nitrates that leach downward from heavily fertilized agricultural land or from cesspools? Under aerobic conditions, especially in the percolating waters of the zone of aeration, they may be expected to remain as nitrates; but in the absence of dissolved oxygen and in a reducing atmosphere, will they change to nitrites and perhaps even to nitrogen gas? Baars (2) presented data from The Netherlands showing that nitrates were decreased in concentration after the dissolved oxygen was diminished. What happened to the nitrogen ions? Will these nitrogen reactions occur in the absence of specific organisms and if not are the necessary organisms likely to be present in deep aquifers?

Similarly, under what conditions in the soil will sulfates be reduced to

sulfur or to sulfides? In what types of waters are the microorganisms commonly associated with such reactions likely to be present? Can the reactions occur in the absence of organisms; i.e. can they be strictly chemical and not biochemical?

These questions about nitrogen and sulfur compounds are especially relevant to the percolation and recharge of ground waters by organic industrial wastes and sewage. Such waters are not likely to be sterile, although the travel of microorganisms may be limited to a short distance.

Biochemical Degradation

Chemical reactions brought about by biological processes have long been subject to quantitative evaluation in surface waters. In the ground, however, they are much more difficult to assess and as a result, relatively little is known about reaction rates, mechanisms, pathways, intermediate steps, and end products.

Ground water differs from surface water, insofar as biochemical degradation is concerned, in several important ways. First, the ratio of surface area of the soil to the quantity of flow is tremendous in ground water. This area-volume ratio will influence the rate of biochemical phenomena, for many of these reactions are accelerated by the presence of large surface areas. Second, detention periods are long, so that even the slower reactions may go far toward completion. Third, ground waters are often anaerobic and frequently under high pressure. Fourth, higher organisms are readily removed by filtration through soil and consequently biochemical action may be limited to the lower forms or perhaps even to enzyme effects. Little, if anything is known about the role and travel of enzymes in ground water. There is a need for quantitative evaluation of all of these factors, and perhaps others, in relation to various organic compounds and to specific types of soils.

A most urgent problem in relation to biochemical degradation involves the persistence of alkyl benzene sulfonates (ABS) and other components of synthetic detergents. As is well known, ABS has been observed to travel through soil for appreciable distances; yet 50 to 90 per cent of it can be removed in the activated sludge process. Furthermore, its half-life in surface streams has been estimated at 16 days, and along the Illinois River, the total ABS in the flowing water was diminished by 37 per cent in 8 days of travel (3). With the slow velocity through ground water, ABS should be stabilized in short distances if experience from surface streams can be transposed to underground aquifers. But can it?

Is the observed persistence of ABS in ground water related to the fact that bacteria are filtered out in the first few feet of flow? What is the effect of anaerobic or reducing conditions on the stability of ABS? Can a soil be "seeded" or "acclimatized" to hasten the degradation of ABS or any other organic compound? To what extent will ABS be adsorbed and desorbed from various types of soils? Can chemical substances be added to alter these reactions? These are all questions that deserve detailed investigation.

Two-Phase Systems

Thus far, this paper has been limited for the most part to dissolved substances in water. There are many problems, however, that involve the atmosphere in the interstices of soil above the ground-water table or phreatic line. In accordance with the gas laws, this atmosphere is in dynamic equilibrium with the dissolved gases and certain ions in the underlying water, especially if the water table fluctuates in elevation or if it is being fed

from water percolating through the overlying soil atmosphere.

The problem is brought into sharp focus by the decomposition and stabilization of sanitary land fills, as described to you by Weaver (4). If this organic material is below the ground-water table, or if it is leached by heavy rainfall or irrigation, organic and inorganic substances will enter the ground water. Many sanitary landfills in the arid Southwest, however, are supposedly "high and dry," perhaps 20 to 100 ft above the water table and seldom subject to leaching by rainfall or irrigation. How can such fills possibly affect ground-water quality?

First of all, they undergo biochemical stabilization, although it may be very slow. Much knowledge is needed about the rates of stabilization and how they are affected by moisture, temperature, composition of waste, mixing with soil, and other factors. In any event, gases of anaerobic decomposition, such as methane, carbon dioxide, and hydrogen sulfide, are produced. These gases diffuse through the soil and are subject to the laws of fluid dynamics. Permeating the atmosphere of soil interstices, they eventually come in contact with the phreatic line or at least its capillary fringe. There, they go into solution in the ground water, to strive for the equilibria of Henry's Law. Although these general mechanisms can be postulated, little quantitative information is available on the actual occurrence and movement of gases through soil and their relation to the quality of water in the upper fringe of the ground-water table. Furthermore, additional data are needed on the rates of diffusion of these dissolved gases downward, laterally, and longitudinally through ground water.

Another group of problems involving the gas phase relate to the low-molecular-weight hydrocarbons, whether of natural origin or resulting from underground storage. Many fresh ground waters, especially from oil-producing areas or from regions where peaty deposits abound, have been observed to contain dissolved methane. Other hydrocarbons have reached ground waters by man-made pollution or by escape from storage.

The foregoing discussion of chemical effects in relation to ground-water pollution is far from exhaustive, but perhaps it will serve to indicate the magnitude and complexity of the problems. The list of research needs could be enlarged many times by including the problems related to specific industries such as metal-finishing, regeneration of ion-exchange resins, oil-field brine disposal, petroleum products, food processing, and many others. Perhaps it is well at this time, however, to consider another major scientific category.

Physical and Mathematical Problems

The physical and mathematical aspects of geohydrology are related primarily to fluid mechanics and especially to hydrodynamics. These subjects have been investigated more thoroughly in ground water than have the chemical aspects. Fortunately, they can be adapted to mathematical analysis, within certain boundary conditions and assumptions. Yet, there are many areas of physical and mathematical research in ground water that need further exploration.

Thanks to Darcy, Boussinesq, Dupuit, Forchheimer, Thiem, Kozeny, Bakhameteff, Casagrande, Muskat, and many others, the classical hydrodynamic and mathematical aspects of ground-water flow have been well developed. The work to date, however, has dealt largely with an inert liquid, a homogeneous soil, and steady-state conditions. There are still many gaps in the knowledge of hydrodynamics in soil.

More needs to be known about the dispersion of a pollutant as water

travels through various types of aquifers. What is the extent and rate of vertical and lateral diffusion under various conditions of permeability and soil characteristics? What are the yardsticks of diffusivity in soil and what are their approximate magnitudes? How can the parameters of longitudinal mixing of unsteady concentrations of waste be evaluated? What will be the effects and mixing of fluids of different densities? Soils are seldom homogeneous and indeed they are frequently interspersed with laminar lenses. How does such nonhomogeneity influence the classical analyses and how does it alter the parameters of vertical, lateral, and longitudinal diffusion?

It is recognized that much research along these lines has already been performed by the oil industry in connection with its water-flooding operations and by ground-water hydrologists concerned with salt-water intrusion. There are still many aspects, however, that deserve more detailed study, especially with respect to recharging operations by means of spreading basins or pressurized wells.

Much of the work in analyzing flow through porous media involves complicated differential equations, conformal mapping, complex variables, and other mathematical procedures. It would seem appropriate, therefore, to utilize computer technology to a large extent in such work. The feasibility of automatic numerical analysis in many problems of ground-water hydraulics is being investigated, but such research is still in its infancy.

Radioactivity

Three major areas of ground-water research involve radioactivity. First, answers are needed about the travel of radioactive substances through soil; their adsorption, desorption, and ion-exchange; their diffusion and dispersion; and their effects on the other substances in soil and water.

Second, there is a need to explore further the use of radioactive substances as tracers to assist in geohydrological investigations. Which substances can be employed with minimum adsorption or chemical change, and with minimum hazard to the subsequent users of the ground water? Can a calculated risk be taken in the use of radionuclides in groundwater that may be consumed by humans.

Third, can deep aquifers be used for the disposal of radioactive material of long half-life without danger to water supplies? What are the possibilities of cross-contamination among aquifers at various depths, especially if they are perforated by abandoned or poorly constructed wells?

Infiltration and the Mechanics of Clogging

To those interested in wastewater reclamation by the recharging of ground-water basins and aquifers, the problems at the interface between free water and the soil are paramount. Knowledge is needed about the mechanics of clogging, whether it be by physical means, chemical action, or biological growth. To what extent must wastewater be purified before it can be recharged through spreading basins, and to what extent for pressurized wells? What are the best parameters for measuring clogging potentials? When the interface has been clogged, what are the best methods for restoring infiltration capacity? What chemicals can be added to prolong the periods between redevelopment or backwashing of wells? Will the use of certain crops in spreading basins increase infiltration capacity or will concomitant problems such as mosquito breeding and transpiration losses rule out such practices? What is the role of sprinkler irrigation in ground-water recharge? Does it have advantages over spreading basins operated intermittently?

Soil physicists, like soil chemists,

have developed their specialty to an advanced stage. Ground-water hydrologists and engineers should draw heavily on the experience and literature of this discipline. Special attention needs to be given to methods by which permeability of soil may be increased, or in certain instances how it may be decreased. What chemical agents can be used to change permeability, without harm to subsequent beneficial uses of the water? If these changes in permeability are produced by wetting agents or surfactants, what will be the effect on travel of other chemical substances and biological organisms? How can certain aquifers best be sealed to prevent the travel of pollution? One example of this problem is salt-water intrusion along coastal regions. In other instances, portions of polluted aquifers might be sealed off to prevent the further encroachment on unpolluted portions. How best can this be accomplished?

There are many more physical and mathematical problems related to ground-water pollution; however, at this time another major scientific category will be considered.

Biological Problems

Mallmann (5) gives a review of the state of knowledge about biological contamination of ground water and indeed he points out many areas where information is sparse or totally lacking. Empirical data have been obtained in many situations for the travel of bacteria through soils of various characteristics but there are no experimental results on the migration of viruses in ground water. There is qualitative proof that viruses can travel great distances through aquifers and several outbreaks of hepatitis have been traced to ground water. No virus epidemics other than hepatitis have been so traced.

It would appear, therefore, that much research is needed on viruses and bacteriophages. Do non-pathogenic forms occur in natural ground waters unaffected by human contamination? How is the travel of viruses in ground water related to the physical and chemical characteristics of the soil? Will they survive in the absence of bacteria or are the two forms synergistic? In a given soil, will viruses and phages travel farther and/or faster than bacteria? What are the effects of syndets and other chemical pollutants on the presence, survival, and travel of viruses in ground water? How can the transmission of viruses through aquifers be prevented or minimized?

Related to the presence and behavior of bacteria and viruses in ground water are the biochemical problems dependent on enzyme action. If bacteria in contaminated water are adsorbed in the first 100 ft or so of travel through an aquifer, do the exo-enzymes from these organisms move freely with the percolating water and exert their influence in biochemical degradation far beyond the limit of bacterial penetration? If so, can recharge wells or spreading basins be inoculated with beneficial bacteria that will aid in the degradation of specific organic substances during ground-water travel? Can extracts of enzymes be used directly? It would appear that the whole field of enzyme chemistry in relation to the organic pollution of ground water is virgin territory for research.

Geology

It would not be prudent to terminate this discussion of research needs without mentioning the geological problems. Indeed, ground water has long been considered the realm of the hydrologist or geohydrologist. It was not until pollution and contamination of ground water became serious that chemists, biologists, and sanitary engineers took proper notice of this important phase of water resources.

Before any field studies of ground-

water pollution can be made, a thorough geological investigation is necessary. The thickness, extent, degree of homogeneity, mineral character, permeability, and other parameters of each aquifer should be known. Such data are tedious and expensive to obtain. Methods are needed to facilitate the gathering and processing of geological information. Perhaps geophysical techniques can be perfected to yield much of this information without penetration of the aquifers and confining strata by numerous test wells which might later cause interpollution of aquifers. As mentioned earlier, there is a need for conversion of mineral analyses to chemical characteristics that can be used for predicting the interaction of soil and water.

Need for Trained Research Personnel

In the list of scientific categories earlier in this presentation, it was noted that the paper will conclude with a brief comment about the greatest need for all in ground-water research today. In summary, there is a need for trained scientists and engineers who understand the fundamental concepts of ground water and want to perform research in this field.

It is easy to enumerate scores of potential research problems, as this paper has done. It is not too difficult to outline the methodology for accomplishing many of these projects. It is probable that financial support for research projects in ground-water pollution can be obtained readily from one or more sources. Physical facilities for conducting such projects are available at many universities and private institutes. The real bottleneck lies in personnel properly trained and inspired to do the work.

There is a great need for publicity to emphasize the importance of ground water in the national economy and the opportunities for stimulating careers in this field.

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MERRY CHRISTMAS

STABILIZATION POND STUDIES IN WISCONSIN

Kenneth M. Mackenthun and Clarence D. McNabb

The impoundment of raw sewage or the effluent of sewage treatment plants as a means of stabilizing the organic wastes contained therein has become increasingly popular in the United States since 1920. The concept is by no means new, since this type of facility has been used for many centuries in Asia (1). In Europe fish culturists have long recognized the value of conserving this rich source of mineral nutrients, and it is now a widespread practice to dispose of municipal sewage to fish culture ponds (2) thus enriching the water and increasing the eventual yield of marketable protein.

The first prolonged attempts to treat sewage in oxidation ponds in the United States were carried out by Caldwell (3) in the southwest where sunlight and temperature were most favorable for maintaining suitable esthetic conditions. The City of San Antonio, Texas, is reported to have utilized the principle as early as 1901. In California, the satisfactory operation of a sewage pond was first observed by Gillespie (4) at Santa Rosa in 1924. Aware of the success of this type of facility in the southwest, the community of Fessenden, North Dakota, began to discharge raw sewage into a diked slough in 1928 (5). Observation of the Fessenden pond indicated that satisfactory operation could be obtained in the northern parts of the United States regardless of severe winter conditions such as those characteristic of the Dakotas. Since then, stabilization ponds for the treatment of raw or partially pre-treated sewage have become very popular among the smaller municipalities and have sprung up in many parts of the country, especially in the southwest, the northern plain states, and more recently in the midwest.

During 1955, Wisconsin became interested in sewage stabilization ponds and an initial group of four such units were constructed and placed in service during the latter part of 1956. Table I presents the design data of three of these units from which monthly samples were collected at designated stations (Figure 1), commencing in May 1957, and continuing until October 1958. In October 1958, milk wastes were added to the Junction City unit, and the unit became loaded far in excess of design data. The processing plant has a whole milk intake which slightly exceeded 31 mil lb in 1959. The average monthly intake for the four peak months (April, May, June, and July) is slightly more than 3⅓ mil lb, and the average monthly intake for the remaining months is about 2¼ mil lb. May was the peak production month with a whole milk intake of 3.7 mil lb. Because of the increased loading, the Junction City unit was again studied on a monthly basis for the calendar year of 1959.

Local climatological conditions influence to a great extent the function of a stabilization unit. The weather during the period of study was generally cloudy, cold, and wet in the northwest section, and quite dry in the central section of the state. The degree of possible sunshine was below

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TABLE I.—Design Data

Stabilization Ponds	Jct. City I	Jct. City II	Jct. City as a Unit (I & II)	New Auburn	Spooner*
Area (acres)	1.75	0.83	2.58	2.7	22.0
Area (sq ft × 10^5)	0.76	0.36	1.12	1.18	9.58
Avg depth (ft)	3.5	3.5	3.5	5.0	5.0
Capacity (mil gal)	2.0	0.95	2.95	4.5	36.0
Detention period (days)	55.0	26.0	81.0	160.0	125.0
Flow (gpd)	—	—	36,000	28,000	288,000
BOD (lb/day)	—	—	60	75	725
Population (1950)	—	—	330	371	2,597
Pretreatment	—	—	None	Sedimentation	Sedimentation
Receiving stream	—	—	Marsh	Marsh	Yellow River
Date placed in service	—	—	10/56	10/56	6/56

* Pond also receives milk wastes from a creamery.

normal for the entire period of study, with the exception of February and May 1958, during which months it was some 20 per cent above the long-term mean. The annual average temperature in the northwest section of Wisconsin is about 42°F. Temperatures averaged below normal for the period of study, creating a deficit of 6 to 10°F in the northwest area and 18°F in central Wisconsin. The normal precipitation for the northwest section of the state averages about 28 in. per year compared to about 32 in. per year in central Wisconsin. During the period of study, there was a 5-in. precipitation surplus in the northwest part, and a deficit of approximately 11 in. in the central portion. In general, the ponds were ice-covered from

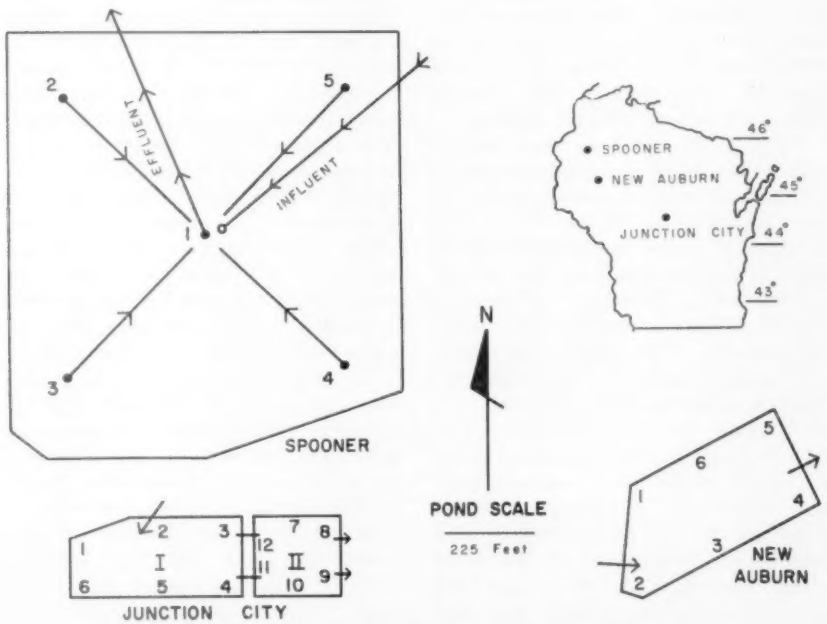

FIGURE 1.—Vicinity map; numbers indicate sampling stations.

the latter part of November until the early part of April with the ice reaching its greatest depth of around 18 in. in February or early March. Two to three inches of snow commonly was present on the ice during this period.

Methods of Study

A measure of pond performance was gained through sampling at regular intervals during 24-hr periods of normal operation when ice covered the pond and again in the spring or summer when the pond was open. Samples were collected from permanent sampling stations (Figure 1) once each month throughout the period of observation. Collections were taken from the upper stratum of water at a depth of six inches. At Junction City and New Auburn, the sampling stations were located 10 ft offshore. The dikes of these ponds were sloped so that the average depth was attained well within this distance. At Spooner, the monthly sampling was done from a boat during the season of open water. Collections from these stations were made between 8 AM and 10 AM at Spooner, between 11 AM and 2 PM at Junction City, and in the interval from 3 PM to 6 PM at New Auburn.

Monthly dissolved oxygen samples were taken at the permanent collecting stations using a device similar to that reported by Welch (6). The Alsterberg (azide) modification of the Winkler method was used for DO determination. Five-day biochemical oxygen demand samples were taken concurrently. The water temperature was measured and pH was determined using an electrometric field unit. A pond mean for DO, BOD, temperature, and pH has been expressed using the results of the determinations from the individual sampling stations. Measurement of the nitrogen and phosphorus components of the pond water, and of total and suspended solids, was made at monthly intervals from a sample of water obtained by compositing 400 ml from each of the sampling stations. All of the chemical analyses were completed according to the procedures prescribed in "Standard Methods" (7).

Bacteriological Determinations

Bacteriological determinations of the most probable number of coliform organisms per 100 ml were made on samples collected monthly from the influent, the effluent overflow, and in the ponds at selected permanent stations more than 50 ft from the inlet. The several pond samples were of surface water and were used to express a pond mean. If a pond was not discharging, the effluent MPN was considered to be equivalent to the average of the pond samples. The bacteriological procedures described by "Standard Methods" were used in this study.

Light Transmission

A light and dark bottle experiment was conducted in the first pond at Junction City on August 26, 1958 to measure the rate of photosynthesis at different depths in the water column. A two-liter sample was composited using equal volumes of water drawn from three different depths at each of four stations. This sample when thoroughly mixed was considered to be representative of average pond conditions. Sub-samples were siphoned into 60-ml DO bottles, and these were handled according to the conventional light-dark bottle technique first described by Gaarder and Gran (8).

The depth of penetration of a sufficient quantity of incident light to maintain photosynthetic oxygen production is important to the structural design of sewage stabilization ponds. A Whitney light meter was used to ascertain light relationships in this study. Its light cell was sensitive to wave lengths of light in the visible range. The instrument was constructed so that scale readings ob-

TABLE II.—Comparative Loading and Discharge Data Based on 24-Hr Studies

Pond	Date	Influent Flow (gpd)	Effluent Flow (gpd)	Loading (lb/day/100,000 sq ft)					Discharge (lb/day)					Reduction (%)				
				BOD	Total N	Inorg. N	Total P	Sol. P	BOD	Total N	Inorg. N	Total P	Sol. P	BOD	Total N	Inorg. N	Total P	Sol. P
Jct. City (I & II)	10-15-57	16,360	19,671	8	3.6	2.9	0.8	0.3	0.7	0.3	0.2	0.03	0.01	92.4	92.6	96.9	96.6	96.6
	8-19-58	15,560	10,720	20	4.5	2.9	1.0	0.7	0.6	0.2	0.2	0.07	0.06	97.2	96.0	99.3	93.6	92.5
	3-3-59	19,973	19,017	101	8.4	4.2	4.4	2.3	40.9	5.1	4.1	4.5	3.6	64.1	45.7	12.8	8.2	—
↓	7-21-59	52,644	23,699	477	39.4	4.9	15.0	6.4	6.8	2.4	0.8	1.6	1.3	98.7	94.6	85.5	90.5	81.9
Jct. City (I Only)	10-15-57	16,360	—	12	5.3	4.3	1.2	0.4	—	—	—	—	—	—	—	—	—	—
	8-19-58	15,560	—	30	6.6	4.3	1.5	1.0	—	—	—	—	—	—	—	—	—	—
	3-3-59	19,973	—	149	12.4	6.2	6.5	3.4	—	—	—	—	—	—	—	—	—	—
↓	7-21-59	52,644	—	703	58.1	7.2	22.1	9.4	—	—	—	—	—	—	—	—	—	—
New Auburn	4-8-58	33,840	*	28	6.8	4.8	1.4	0.9	10.7	7.5	5.3	—	1.1	67.7	5.7	6.5	—	—
↓	8-19-58	15,027	*	43	8.4	5.5	2.0	1.6	6.0	2.2	0.1	1.0	0.8	88.3	78.2	98.2	54.1	58.1
Spooner	12-10-57	185,700	185,700	55	9.2	4.3	—	1.4	51.0	28.9	14.6	—	15.5	90.3	67.2	64.5	—	—
↓	8-11-58	300,960	144,000	54	7.1	4.1	2.9	2.0	33.5	13.2	2.9	8.0	6.6	93.4	80.7	92.6	71.0	65.8

* Pond did not discharge during study. Theoretical discharge flow assumed to be same as influent. Reduction is calculated on concentration in end of pond opposite influent.

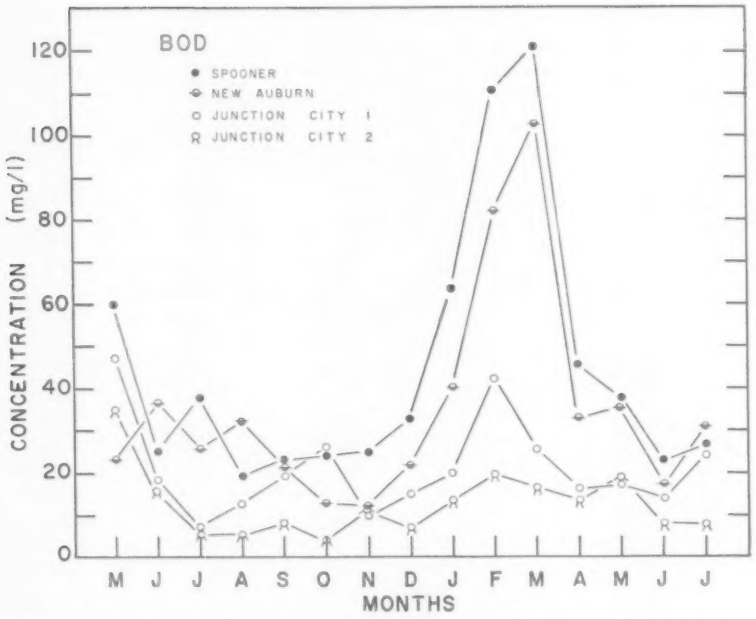

FIGURE 2.—Monthly composite BOD concentrations, May 1957 to July 1958.

tained beneath the surface of the water were directly related to a reading of the incident light intensity. The percentage of incident light transmitted through snow and ice was measured in March 1958. To obtain these readings, the light cell was held firmly against the lower surface of the ice. The rate of light absorption in the water was studied under conditions of ice cover and at several times during the open water season. Measurements were taken at three or more stations well out in the ponds, and these results were used to obtain a pond mean. Similar data were collected on two Wisconsin lakes for the purpose of comparison.

Chemical Conditions

Conditions encountered in stabilization ponds are directly related to the pond loading. This study gave an excellent opportunity to observe the effects on the stabilization mechanism of a gradation in pond loading ranging from a low of 8 lb of BOD/day/100,000 sq ft, to a high of 703 lb of BOD/day/100,000 sq ft as calculated for the first unit at Junction City (Table II).

BOD Values

The month-to-month fluctuation in BOD within a stabilization pond follows the same general trend regardless of the loading (Figures 2 and 3). In general, the values are low during the summer, increase during the fall and early winter, and reach a peak during March after which they rapidly drop following the disappearance of ice cover. In loadings of 10 to 20 lb of BOD/day/100,000 sq ft, minimum summer BOD values range from 10 to 15 mg/l in the stabilization pond, and maximum winter BOD values range upward to about 45 mg/l. As the loading is increased to 30 and 40 lb of BOD/day/100,000 sq ft, the minimum summertime BOD readings are in the vicinity of 20 mg/l and the maximum March reading is 100

mg/l. Increasing the BOD loading to 55 lb/day/100,000 sq ft likewise increases the maximum March reading to 120 mg/l. As shown in the 1959 Junction City studies, a BOD loading ranging from 150 to 700 lb/day/100,000 sq ft produces a BOD in the stabilization pond of 280 mg/l in March. It is felt that the optimum loading at this latitude is near 50 lb of BOD/day/100,000 sq ft of pond surface.

Nitrogen Concentrations

The general trend of the nitrogen curve is very similar to the BOD curve (Figures 4 and 5). The highest concentration within the stabilization pond is again reached in March. Generally speaking, organic nitrogen forms the bulk of the total nitrogen present in the stabilization pond with the exception of the high wintertime concentrations. During the period of ice cover, the ammonia nitrogen increases until it makes up nearly 80 per cent of the total nitrogen. The exception to this occurred at Junction City during July and August 1959, at which time the organic nitrogen showed a 100 per cent increase over previous concentrations. Highest nitrogen concentrations occurred at Junction City during March 1959, when Pond I contained 34 mg/l ammonia nitrogen and 11 mg/l organic nitrogen.

Phosphorus Concentrations

Monthly soluble phosphorus concentrations in the stabilization ponds were more erratic than were the nitrogen and BOD concentrations (Figures 6

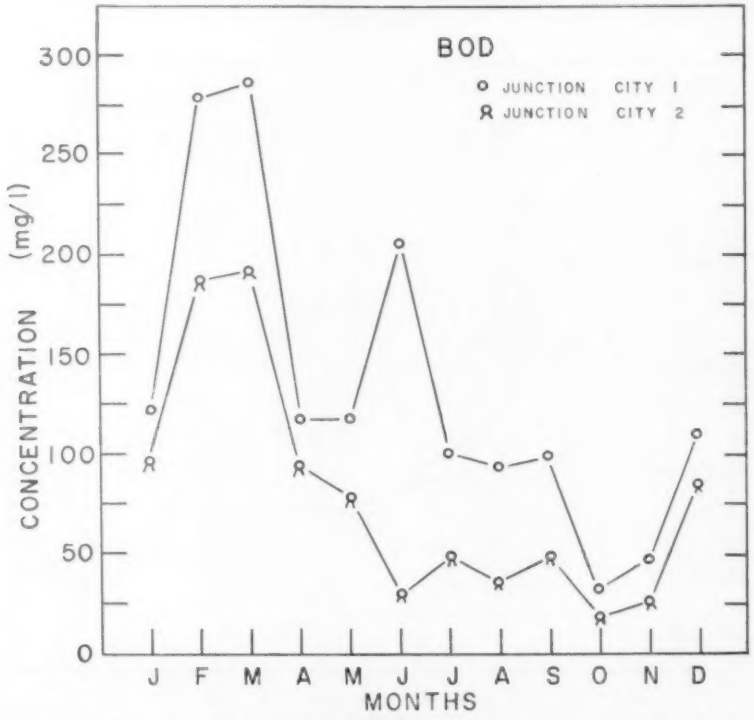

FIGURE 3.—Monthly composite BOD concentrations for Junction City ponds, 1959.

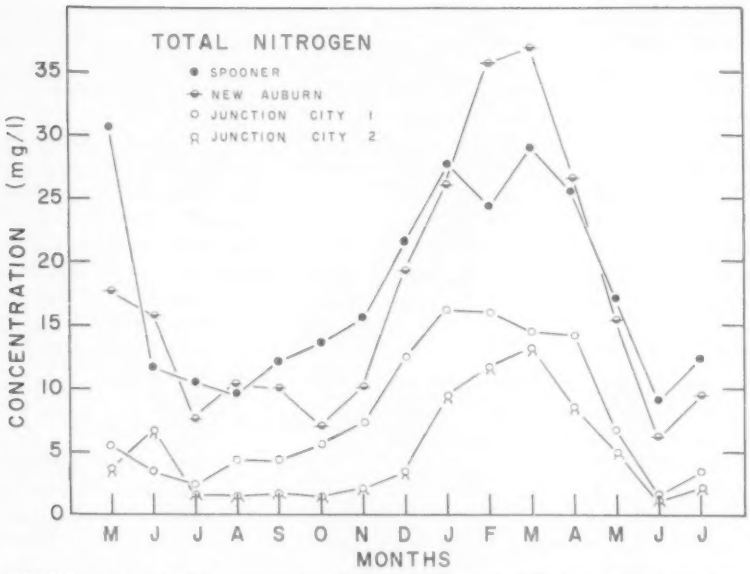

FIGURE 4.—Monthly composite total nitrogen concentrations, May 1957 to July 1958.

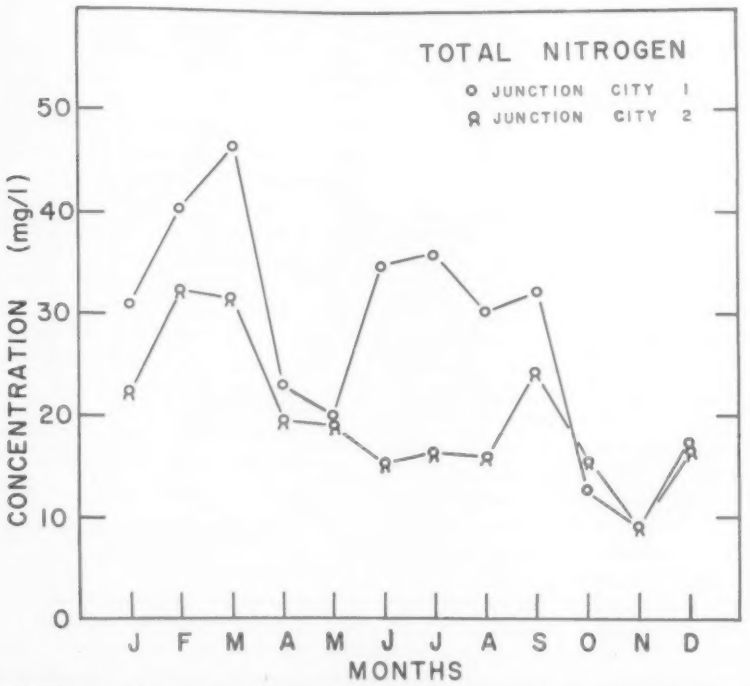

FIGURE 5.—Monthly composite total nitrogen concentrations for Junction City ponds, 1959.

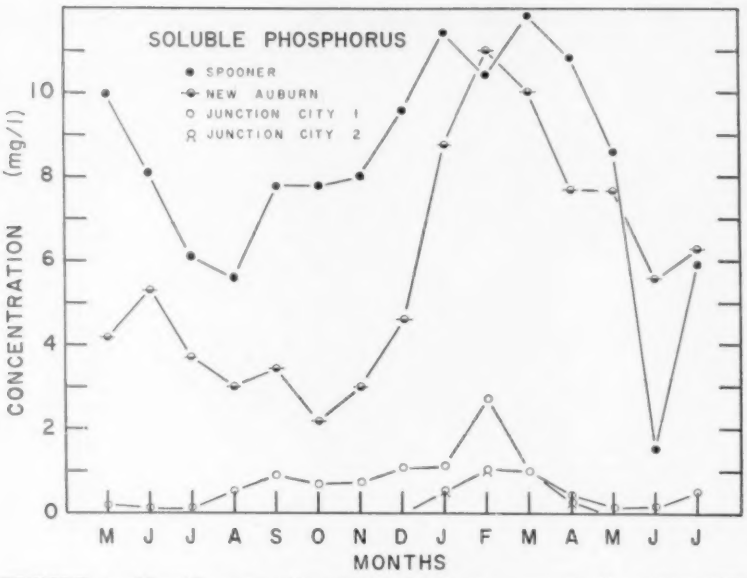

FIGURE 6.—Monthly composite soluble phosphorus concentrations, May 1957 to July 1958.

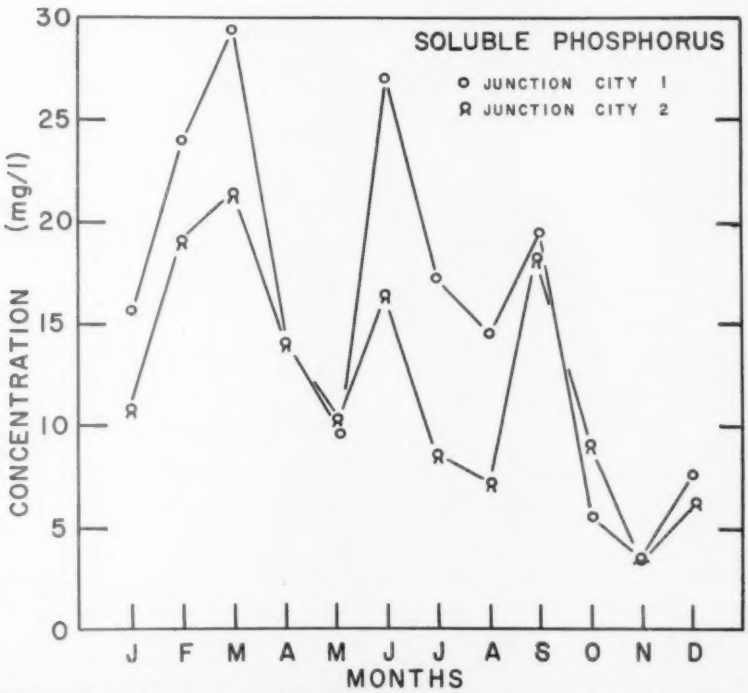

FIGURE 7.—Monthly composite soluble phosphorus concentrations for Junction City ponds, 1959.

TABLE III.—Mean Concentrations of Dissolved Oxygen (mg/l) and Per Cent Saturation in Surface Samples

Month	Jct. City I		Jct. City II		New Auburn		Spooner	
	DO (mg/l)	Sat. (%)	DO (mg/l)	Sat. (%)	DO (mg/l)	Sat. (%)	DO (mg/l)	Sat. (%)
1957 May	9.5	90	11.3	110	1.4*	13	0.4*	3
June	14.4	171	12.4	147	0.2*	2	8.5	92
July	11.2	133	5.5	66	7.5	88	0.3	3
Aug.	5.5	64	10.8	127	8.2	100	8.3	98
Sept.	10.0	98	12.0	117	11.3	113	3.1	29
Oct.	15.1	143	9.8	92	5.7	52	6.0	55
Nov.	18.8	—	24.4	—	2.2	—	13.5	—
Dec.	13.3	—	20.5	—	0.4*	—	1.4*	—
1958 Jan.	2.3*	—	7.4*	—	0.2*	—	0.5*	—
Feb.	0.1*	—	2.8*	—	0.4*	—	0.8*	—
Mar.	13.8*	—	4.6*	—	0.0*	—	0.0*	—
Apr.	24.2	245	18.8	185	9.4	85	2.5*	21
May	21.7	225	15.4	153	15.3	166	0.9	9
June	24.6	270	10.3	113	13.1	147	27.0	297
July	19.2	225	8.6	100	19.5	232	19.2	229

* Hydrogen sulfide odors present.

and 7). The peak concentration occurred during the winter period, and the minimum concentration was generally achieved in late fall. Depending on the initial loading, the soluble phosphorus varied from a high of near 30 mg/l to a low of < .01 mg/l.

Hydrogen Sulfide

Odors of hydrogen sulfide gas were associated with periods of prolonged anaerobic conditions (Table III). These odors were observed to develop beneath the ice in winter and continue into early spring. It seems probable that hydrogen sulfide in sensible concentration was associated only with prolonged periods of anaerobiosis since low dissolved oxygen values observed in the morning samples at Spooner in July 1957, and again in May 1958, presumably caused by near DO depletion at night, did not result in perceptible odors on those dates. The coincidence of odors and a relatively high dissolved oxygen level in the first pond at Junction City in March 1958, was due to oxygen depletion in the lower portion of the pond. It appears that the lower stratum of Pond II at Junction City similarly gave rise to hydrogen sulfide during the winter.

Under BOD loadings up to 20 lb/day/100,000 sq ft, no odors were detected in the vicinity of the pond during the open water period. With an increase in loading from 25 to 40 lb, odors were detected for a period of approximately two weeks in the vicinity of the pond following ice break up. Odors up to four weeks in duration during the early spring were associated with BOD loadings of 50 to 60 lb/day/100,000 sq ft. Following the introduction of the heavy BOD loading into the Junction City installation, odors were detected at all times with the exception of the sampling period in the month of October.

The pH, during the studies at Junction City, ranged from 7.0 to 7.5 in the mid-winter period to a maximum of 10 to 11 during the summer months. Following the introduction of milk processing wastewater, the pH never exceeded 8.0 in the first pond at Junction City, and minimum readings were 6.6 and 6.9. At New Auburn, the minimum winter readings ranged from 6.9 to 7.1 to a maximum of 9.0

during the summer months. The Spooner installation showed less variation in pH, with a range from 7.7 to 9.3. Maximum temperatures were, of course, reached during the late summer period and were in the neighborhood of 25.0 to 27.5°C for all of the stabilization ponds.

Coliform Reduction

Reductions in coliform organisms were greater than 98 per cent, more than 87 per cent of the time. There is a greater reduction in summer than during the more severe winter conditions. Prior to the introduction of milk wastewater, the effluent of the Junction City unit (monthly grab samples) ranged from a minimum MPN of 4 in June to a maximum of 49,000 in February. Following the introduction of milk processing wastewater, the Junction City effluent revealed MPN ranging from 20,000 to a maximum of 5,400,000. The New Auburn installation gave MPN readings in the effluent of 4,600 to a maximum of 457,000. The Spooner installation ranged from 170,000 to 1,700,000.

Solids Settlement

Total solids were also generally lowest in summer and highest during the winter season. The studies on the Junction City pond indicated total solids ranging from 225 mg/l during June and July to a maximum of 375 mg/l in January. The range at the New Auburn installation was 330 to 450 mg/l. The total solids in the Spooner pond ranged from 390 to 570 mg/l, and the 1959 studies at Junction City ranged from 330 mg/l to a maximum of 900 mg/l reached during the month of March. Solids settle to the bottom and are utilized in the anabolic function of the benthic organisms. Decomposition during the season of optimum temperature and dissolved oxygen is inadequate to completely oxidize this material. Partially decomposed material tends to accumulate on the pond bottom. This layer of sediment can usually be differentiated into a layer of compact, black, organic material, attaining a maximum depth of about two centimeters in the two years since initial operation. Superimposed

TABLE IV.—Daytime Surface Temperature and Ice and Snow Cover at Approximately Four-Week Intervals

Month	Temperature (°C)				Ice Cover (in.)			
	Ponds				Ponds			
	JC I	JC II	NA	S	JC I	JC II	NA	S
1957 May	13.5	14.5	13.0	11.0	—	—	—	—
June	25.5	25.5	21.5	23.0	—	—	—	—
July	25.0	26.0	24.5	24.5	—	—	—	—
Aug.	24.0	24.0	26.0	24.5	—	—	—	—
Sept.	14.5	14.5	16.0	14.0	—	—	—	—
Oct.	13.0	13.0	11.5	12.0	—	—	—	—
Nov.	3.0	2.0	2.0	1.0	3	3	4	6
Dec.	1.0	1.0	1.0	1.0	6*	6*	10*	12
1958 Jan.	1.0	1.0	0.5	0.5	10*	10*	15*	15*
Feb.	0.5	1.0	0.5	1.0	13*	15*	17*	18*
Mar.	1.5	1.5	1.0	1.0	12*	15*	16*	18*
Apr.	16.5	15.0	11.0	7.5	—	—	—	—
May	17.5	15.5	19.5	16.0	—	—	—	—
June	20.5	20.5	21.5	25.0	—	—	—	—
July	25.0	25.0	24.5	25.0	—	—	—	—

* Ice covered with one or more inches of snow.

TABLE V.—Light Transmission Through Snow and Ice

Pond	Date (1958)	Mean Snow Thickness (in.)	Mean Ice Thickness (in.)	Mean Percentage Light Transmitted
Junction City				
Pond I	3/10	1.3	12	6.5
Pond II	3/10	1.5	15	10.2
New Auburn	3/13	2.0	16	3.9
Spooner	3/15	3.0	17	4.7

on this layer was an upper layer of recently settled particles containing microscopic fragments of decomposing sewage solids and well-colored clumps of algae. The particles in this layer were loosely arranged, and the total depth of this layer also was approximately two centimeters.

Air Temperatures

Daily fluctuations in air temperature are strongly superimposed on the surface water of a stabilization pond. In northern climes, this may lead to the formation of ice as winter approaches. Daytime temperatures of the surface water of ponds in Wisconsin are indicated in Table IV, along with data concerning the presence of ice and snow and the thickness of the ice. The ponds were completely closed by ice in the months indicated except for small openings directly above the inlet. They were effectively sealed from interaction with the atmosphere for approximately 40 per cent of the year. Snow was usually present on the ice at the times of winter sampling.

Light Absorption

Variation in the intensity of solar radiation among seasons influences the potential rate of photosynthesis in a pond, both because of the diminished heat budget and the reduced amount of energy available for the photochemical reaction. The presence of ice with an overlying layer of snow in winter limits further the amount of relatively poor incident light energy that reaches the water. An estimate of the percentage of incident light that passes through typical winter cover is indicated in Table V. The drastic reduction is apparent, ranging between 90 and 96 per cent absorption. It appears from the data that the quality of the ice is a factor in determining the percentage of light transmitted.

The rate of light absorption with water depth is indicated in Table VI by measurements of the level at which specific percentages of incident light remained. When the relationship between the reduction in light and the thickness of the layer of water through which it has passed is expressed graphically on a semi-logarithmic plot, a straight line is obtained if materials in suspension are uniformly distributed. If these data are thus plotted, a straight line relationship was consistently approximated at Spooner and quite regularly at Junction City and New Auburn. Variations from a straight line plot in the latter ponds were found to coincide with a vertical stratification of the phytoplankton.

The light penetration data collected in March 1958 may be considered typical for periods when snow covers the ice. The work of Birge and Juday (9), reported recently by Neess and Bunge (10), indicates that the absorptive quality of clear ice is very similar to water although the addition of air bubbles or other particulate matter somewhat reduces the transmissibility of energy. In the absence of snow, light penetration in the ponds would be much improved.

The depth of the euphotic zone, indicated in Table VI as the level at which one per cent of the incident light remains, was found to extend only a few inches beneath snow and ice. In the season of open water, it was generally between two and three feet deep in the ponds at New Auburn and

TABLE VI.—Light Penetration in Sewage Oxidation Ponds and Two Wisconsin Lakes in 1958

Location	Date	Mean Depth (in.) at which Indicated Percentage of Incident Light Remains				Remarks
		(50%)	(25%)	(10%)	(1%)	
Junction City Pond I	3/10	—	—	—	10	1.3 in. snow, 1 in. ice
	4/15	14	22	33	—	>1% at bottom (45 in.)
	5/20	3	6	10	21	
	6/16	13	25	33	43	
	7/24	12	18	23	30	
	8/9	12	22	37	41	
	8/26	7	18	32	—	>1% at bottom (45 in.)
New Auburn	3/13	—	—	—	>1	2.0 in. snow, 16 in. ice
	4/24	2	5	8	20	
	6/18	6	13	19	25	
	7/23	4	8	14	26	
	8/19	4	8	15	27	
Spooner	3/15	—	—	—	7	3.0 in. snow, 17 in. ice
	4/10	4	8	14	27	
	4/29	3	6	11	23	
	5/21	3	6	11	24	
	6/19	6	12	19	33	
	7/23	3	6	11	23	
	8/12	4	9	17	32	
Lake Waubesa (Dane County)	6/13	18	47	98	217	Eutrophic lake
Pine Lake (Waukesha Co.)	6/12	82	244	406	762	Meso-oligotrophic lake

Spooner. Pond I at Junction City exhibited the widest variation in extent of the euphotic zone, and on occasion all portions of the pond received adequate light for photosynthesis. Similar data are found for two southern Wisconsin lakes. Penetration of light into the wastewater ponds was strikingly less than into these lakes, as well as into most other natural bodies of water for which data are available (9)(11)(12).

Photosynthesis

Fitzgerald and Rohlich (1) recognized that the phytoplankton in stabilization ponds are responsible through photosynthesis for maintaining the aerobic environment in which satisfactory waste treatment occurs. An ex-

TABLE VII.—Light and Dark Bottle Oxygen Production at Different Depths in Junction City Pond I on August 26, 1958

Time (PM)	Depth (in.)	Surface Light Remaining (%)	Approx. Mean Light (ft-c)	DO* Change (mg/l)		O_2 Production (mg/l/hr)		Respiration (mg/l/hr)
				Light Bottle	Dark Bottle	Net	Gross	
12:15 to 2:15	3	66	2,640	+2.10	−0.85	+1.1	1.5	0.4
	15	26	1,040	+1.10	−0.85	+0.6	1.0	0.4
	30	7	280	−0.25	−0.85	−0.1	0.3	0.4
	42	1.5	60	−0.50	−0.90	−0.3	0.2	0.5

* DO determinations were made in triplicate.

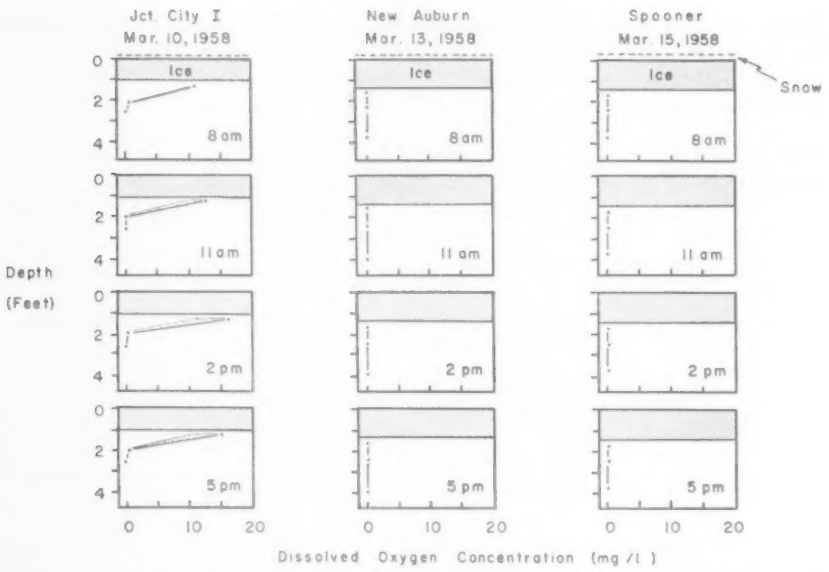

FIGURE 8.—Diurnal variation of DO at different depths in late winter. Stippled areas represent the difference between initial DO concentrations in the morning and those observed at successive sampling times. Shaded areas are ice.

periment was conducted in the first pond at Junction City during August 1958 to measure the rate of this process at various depths. Light and dark bottles were suspended in the water at the levels indicated in Table VII for a period of two hours near midday. The approximate light intensity at each depth was calculated, after having measured the percentages of surface light remaining, from the mean incident intensity taken in foot candles at one-half hour intervals from noon until 2 PM. The water temperature at the time of the experiment decreased regularly with depth from 22.5°C at 1 in. below the surface to 19.5°C just off the bottom at 46 in.

The respiratory use of oxygen in the aluminum covered jars (dark bottles) was essentially the same at each level in the pond. The observed difference in vertical temperature had no measurable effect on the results of the experiment since, if such were the case, respiration rates would have been greater at the surface and would have decreased toward the bottom. Production of dissolved oxygen by the algae was found to decrease with depth. The compensation point, or the level at which the rate of photosynthetic oxygen production was equivalent to total respiratory use occurred just above 30 in. Respiratory consumption of oxygen below that depth exceeded production. If conditions similar to those of the experiment actually existed in the pond, a dissolved oxygen deficit would occur in the lower stratum.

It appears that light was the principal factor causing vertical differences in the rate of oxygen production. This rate was five times greater near the surface than at a depth of 2.5 ft. The lower limit of gross photosynthesis lay near the depth at which one per cent of the incident light remained. The latter level is by definition the lower boundary of the euphotic zone,

and all appreciable photosynthesis occurs above it.

Ice Cover

The *in situ* effects of photosynthetic aeration in the stabilization ponds were apparent from dissolved oxygen data collected at regular intervals from dawn until dusk on days in late winter, spring, and summer. Near the end of the winter stagnation period, the New Auburn and Spooner impoundments were found to be completely anaerobic (Figure 8). In contrast to this, the first pond at Junction City had substantial quantities of dissolved oxygen confined to a narrow stratum just beneath the ice. Complete ice cover prevented the occurrence of surface aeration; consequently, the oxygen present originated solely through photosynthesis. The concentration at the uppermost sampling depth increased during the day causing the vertical stratification evident at 8 AM to become further accentuated. A maximum vertical gradient was observed at 2 PM when a difference of 17 mg/l of dissolved oxygen occurred in 1.5 ft of water.

Between 4 and 7 per cent of the incident light passed through the snow and ice cover of the ponds on these dates (Table V). Very little light energy, therefore, passed into the water. The euphotic zone extended for a few inches at Junction City and Spooner, and was nearly absent in the pond at New Auburn. The water of the latter was more darkly colored, presumably from the humus of the bottom.

Water Temperatures

Temperature of the water in March was not conducive to rapid metabolic activity of the biota (Table IV). At mid-day, it was typically near 1°C a few inches beneath the ice and increased gradually to 3.5°C in the more dense water just off the bottom.

Oxygen Depletion

It is thus apparent that the algae in the euphotic zone of the pond at Junction City produced oxygen by photosynthesis in excess of oxygen loss in the upper stratum of water. Poor light intensity and low water temperature would be expected to have a limiting effect on photosynthesis but were not completely inhibitory. Oxygen transfer to the unproductive deeper portion of the pond was not rapid enough to meet the demand that existed there. The lower stratum was anaerobic throughout the day. Concentrations of dissolved oxygen observed in the first samples of the morning from just beneath the ice were of such a magnitude as to indicate that aerobic conditions prevailed at that depth during the previous night.

Oxygen depletion existed in the ponds at New Auburn and Spooner, because the phytoplankton was unable to sustain a photosynthetic rate sufficient to offset oxygen consumption so that an accrual could occur. Very poor light transmission into the pond at New Auburn was especially detrimental to photosynthesis and algal growth. While a small amount of photosynthesis may have occurred in these impoundments, the rate of oxygen uptake exceeded the rate of production.

Ice disappeared from the ponds on April 4 and 5 in 1958. Diurnal vertical changes in dissolved oxygen concentration were studied shortly thereafter.

The first pond at Junction City was supersaturated with dissolved oxygen at nearly all levels from early morning and throughout the day on April 15 (Figure 9). Dissolved oxygen concentrations in the upper three feet of water increased between each of the times of sampling. A strong vertical gradient developed in the afternoon with a maximum difference of 12.7 mg/l noted at 6 PM between samples taken from 3 and 42 in. The high

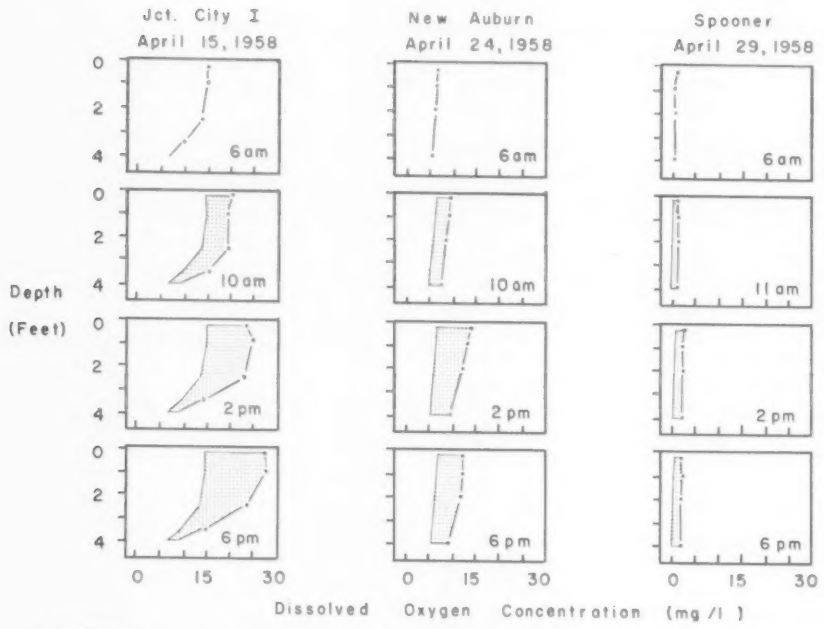

FIGURE 9.—Diurnal variation of DO at different depths in early spring. Stippled areas represent the difference between initial DO concentrations in the morning and those observed at successive sampling times.

concentration of oxygen present at 6 AM indicates that the pond remained aerobic during the preceding night.

Sizable quantities of dissolved oxygen existed at all levels sampled in the pond at New Auburn on April 24 (Figure 9). Gains in concentration were observed at each depth during the morning and early afternoon. The upper stratum of water reached oxygen saturation by 2 PM. In the interval of time between 2 and 6 PM, there was a decrease in concentration at all levels. A strong vertical gradient did not develop in the pond on this date. A depletion of oxygen did not occur during the night prior to sampling, since nearly 6.0 mg/l were present in the pond at dawn.

Figure 9 illustrates that meager dissolved oxygen concentrations were present at various depths in the pond at Spooner on April 29. Small oxygen gains were observed at each sampling depth during the morning and early afternoon, while a slight loss of oxygen was detected during the late afternoon hours. The vertical distribution of oxygen was found to be uniform throughout the day. Metabolic activity within the pond during the night before sampling caused near depletion to exist at dawn.

Photosynthetic oxygen originated in the euphotic zones of these ponds. The depth of this layer on the April sampling dates is indicated in Table VI. At Junction City, the entire pond was bathed in light sufficient for sustained photosynthesis with greater than one per cent of that incident remaining on the floor of the pond. In the impoundments at New Auburn and Spooner, this zone was appreciably more shallow, being slightly less than two feet deep.

Pond Recovery

These data indicate that the rate of recovery from winter stagnation varied among the ponds. As the water temperature rose (Table IV), a completely aerobic environment was established at Junction City and New Auburn within two weeks after the ice melted. The Spooner installation was just beginning to exhibit the diurnal excess of oxygen 24 days after it opened. Hydrogen sulfide odors, associated with anaerobic conditions, were detected only in the water samples from the latter pond.

Typical changes in the vertical distribution of dissolved oxygen between dawn and dusk on summer days are indicated in Figure 10. The depth at which 1 per cent of the incident light remained in the ponds on these dates of study was between 2 and 3 ft, except at Junction City where this layer extended to 41 in.

The Spooner installation was studied on two occasions. On June 19 the upper three feet of water in that pond were supersaturated with dissolved oxygen early in the morning. Aerobic conditions prevailed during the previous night. Concentrations increased in the upper stratum as the day progressed, thus amplifying the stratification present at sunrise to a maximum difference in late afternoon of nearly 30 mg/l between surface samples and those taken at a depth of 4 ft. While the concentration at the latter level was small, oxygen depletion was not observed.

On August 12, the margin by which diurnal aeration exceeded nocturnal consumption in the Spooner pond was much smaller. The graphs of Figure 10 for that date show that the water was very nearly depleted of dissolved oxygen during the night preceding sampling. As oxygen increments were added in the intervals between times of sampling, a vertical gradient became established, characterized in late afternoon by values at the surface

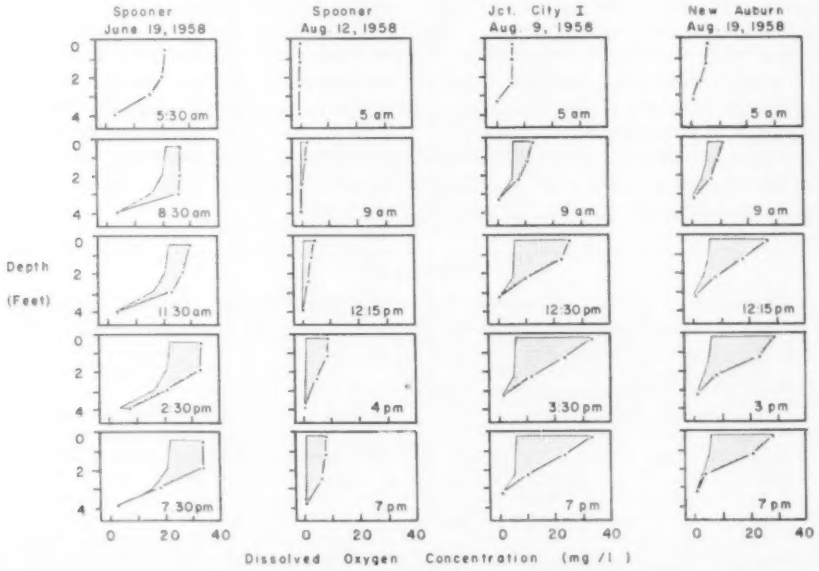

FIGURE 10.—Diurnal variation of DO at different depths in summer. Stippled areas represent the difference between initial DO concentrations in the morning and those observed at successive sampling times.

near saturation. While at a depth of four feet, no dissolved oxygen was present.

The data from Spooner on these two dates served to illustrate that during normal operation in the summer, widely different dissolved oxygen relations may be observed in a pond. Following recovery from winter stagnation, a given pond may conserve a large excess of dissolved oxygen during a period of a few days or weeks and then under seemingly similar climatic conditions revert to a situation in which a delicate balance exists between diurnal net gain and nocturnal loss.

Maximum DO Concentrations

In the present series, the Junction City and New Auburn impoundments were studied at a time when maximum dissolved oxygen concentrations were present. The diurnal vertical distribution of oxygen on the dates of sampling in August (Figure 10) was similar in these ponds. Large gains in dissolved oxygen were made during the day only in the upper two feet of water. The concentration in the lower portion of the ponds was poor with anaerobic conditions prevailing near the bottom. The odor of hydrogen sulfide was present in water drawn from the lowest depth. Extreme vertical stratification with a difference of between 25 and 35 mg/l of dissolved oxygen in a little more than 3 ft of water was evident by late afternoon. The concentrations of oxygen noted at 5 AM in the upper portion of these ponds were of such a magnitude as to indicate that oxygen depletion did not occur during the previous nights.

The steep dissolved oxygen gradients observed in the ponds on days of sampling during the spring and summer indicate poor mixing of the water columns by wind-driven currents. The oxygen produced by the phytoplankton in the upper strata was not translocated to deeper layers. The cause for this appears to lie in vertical temperature gradients which were of sufficient magnitude to give the water columns considerable stability (13).

Acknowledgment

Acknowledgment is gratefully given to Mr. T. F. Wisniewski, Director of the Committee on Water Pollution, for his encouragement throughout the course of this study; to Miss Dorothy McNall, Chemist of the State Laboratory of Hygiene, for the chemical determinations on the collected samples; to the engineers of the State Board of Health for their assistance in the 24-hr studies; and to the many others who "became a part" of a study of this magnitude.

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MEETINGS OF INTEREST

1961

Dec. 26–31 **American Association for the Advancement of Science,** Denver, Colo. AAAS, 1515 Massachusetts Ave., N. W., Washington, D. C.

1962

Jan. 15–26 **Basic Radiological Health,** Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio (to be repeated at Las Vegas, Nev., Feb. 26–Mar. 9; at the Taft Center Apr. 23–May 4; and at Rockville, Md., May 7–18.

Jan. 22–25 **National Plant Engineering and Maintenance Show and Conference,** Convention Hall, Philadelphia, Pa. Clapp and Poliak Inc., 341 Madison Ave., New York 17.

Jan. 25–27 **National Society of Professional Engineers,** King Edward Hotel, Jackson, Miss. NSPE, 2029 K St., N. W., Washington 6, D. C.

Feb. 5–9 **Recent Developments in Water Bacteriology,** Robert A. Taft Sanitary Engineering Center (See above for address).

Feb. 13–14 **Fourth Sanitary Engineering Conference** (Subject: Water Distribution Systems), University of Illinois, Urbana, Ill. Professor Ben B. Ewing, Department of Civil Engineering, University of Illinois; or C. W. Klassen, Chief Sanitary Engineer, Department of Public Health, Springfield, Ill.

Feb. 19–23 **American Society of Civil Engineers,** Hotel Shamrock Hilton, Houston, Tex. W. W. Wisely, ASCE, 345 East 47th St., New York 17.

Mar. 20–29 **American Chemical Society,** 141st National Meeting, Washington, D. C. American Chemical Society, 1155 16th St., N. W., Washington 6, D. C.

STORM-WATER OVERFLOWS FROM COMBINED SEWERS

H. H. Benjes, P. D. Haney, O. J. Schmidt, and R. R. Yarabeck

As more and more cities provide treatment for their wastes, more attention is being given to sewage lost through overflows from combined sewer systems (1)(2)(3). If substantial volumes of sewage are allowed to overflow without treatment, the objective of water pollution abatement is defeated.

This paper is concerned with (*a*) determining the frequency, duration, and the amount of sanitary sewage in combined sewer overflows, and (*b*) determining the practical limitations on the maximum capacity for storm-water runoff that can be provided in intercepting sewers and treatment plants for effective pollution abatement.

During storms the flow in combined sewer systems may be 100 to 200 times the amount of the sewage flow. Because it is not economically feasible to design intercepting sewers and sewage treatment facilities to handle such flows, only a fraction of the combined flow can be intercepted and brought to a plant for treatment. The quantity of flow so intercepted is often expressed in terms of its ratio to the average annual dry-weather flow (DWF) of sanitary sewage. ("DWF" is defined as average annual dry-weather flow.) This ratio is referred to as the "interception ratio."

Peak Dry-Weather Flow

Although the interception ratio is usually expressed as a function of the average dry-weather flow, actually the basic consideration is how much storm-water capacity should be provided in the interceptor in excess of that capacity needed to carry the peak dry-weather sewage flow. Storm-water runoff and peak dry-weather flow may appear in the interceptor simultaneously; and, therefore, the peak dry-weather flow is of greater significance than the average dry-weather flow in determining the most feasible interception ratio.

The ratio of peak-to-average dry-weather flow varies widely, depending on the size of the community. Where a community of 20,000 people will have a ratio of peak-to-average dry-weather flow of about 3.0, a community of 500,000 may have a similar ratio of only 1.5. Before even considering the amount of storm-water runoff to be intercepted in these two communities, it will be necessary to use an interception ratio, as previously defined, for the smaller community of twice that for the larger community in order to carry just the peak dry-weather flow. Arbitrary selection of an interception ratio, derived from average dry-weather flow, for all cities, regardless of size, is unrealistic because it fails to take into account the great variation among cities of different sizes in the ratio of peak-to-average dry-weather flow. It is considered that the practice of relating interceptor capacity to average dry-weather flow should be changed. A better concept would be to measure the interceptor capacity in terms of the peak dry-weather flow. Interception ratios would then be calculated by dividing intercepting sewer capacity by peak dry-weather flow.

In a few cities facilities have also

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been provided for treatment of the bypassed combined sewage. Because of the large flows involved and difficulty in obtaining adequate sites, such treatment is generally limited to a relatively short period of sedimentation, skimming, and chlorination with the settled solids discharged to the intercepting sewer.

Low-Intensity Storms

The low-intensity storms are important in determining the frequency and duration of overflow from combined sewers. McKee (4) made a detailed study of low-intensity storms using the Boston, Mass., records for the June through November period for 1934 to 1945 inclusive. He found that a rainstorm of 0.04 in./hr will produce storm runoff equal to the DWF and that 0.03 in. is necessary to wet-down the area before runoff begins. Thus, in Boston, a rainstorm of 0.01 in./hr, after initial wet-down, will produce runoff equal to the DWF. Palmer (2) and Johnson (3), in independent studies elsewhere, arrived at practically identical results. Palmer's conclusions were based on actual field measurement and observation; McKee's were based on an analysis of published records. Shifrin and Horner (5), at St. Louis, estimated that 0.04 in. of rainfall is required before surface runoff begins from impervious areas. Their findings show that the rainfall required to produce runoff from pervious areas varies, being dependent on duration and intensity but is never less than 0.12 in. They also found that the DWF of sanitary sewage is equivalent to 0.007 in./hr/acre.

Sanitary Sewage Loss by Overflow

McKee (4) determined how much of the sanitary sewage is lost to the receiving stream during any specific rainstorm. The percentage of the DWF escaping is dependent on the intensity of the storm and the capacity of the interceptor. A partial summary of his findings is presented in Table I.

TABLE I.—Interceptor Capacity and Sanitary Sewage Lost

Interceptor Capacity (× DWF)	Runoff (in./hr)	DWF Escaping (%)
2	0.05	67
3	0.05	50
5	0.05	17
9	0.05	0
2	0.10	82
3	0.10	73
5	0.10	55
9	0.10	18
2	0.50	96
3	0.50	94
5	0.50	90
9	0.50	82

It is apparent from these figures that a large part of the sanitary sewage escapes to the receiving stream during low-intensity storms even if the interceptor capacity is 5 × DWF.

McKee (4) carried this phase of his study further by combining the rainfall occurrence and the per cent of sewage lost to determine the per cent of total sewage lost on an annual basis. He found that rainfall sufficient to cause runoff occurs about 5.65 per cent of the time. He also found that with an interceptor capacity of 2 × DWF, 2.7 per cent of all sanitary sewage will escape, or 97.3 per cent will be intercepted. If the interceptor capacity is 5 × DWF, 1.2 per cent of all sewage will escape, or 98.8 per cent will be intercepted. Stanley (6), in his discussion of McKee's paper, reported that at Chicago with an interceptor capacity of 2 × DWF, 2.9 per cent of all sanitary sewage will escape; and if the interceptor capacity is 5 × DWF, 0.4 per cent of all sanitary sewage will escape. Stanley also pointed out that rainfall intensities equal to or greater than 0.04 in./hr will occur 1.6 per cent of the total time at Chicago, and 1.7 per cent of the total time at Minneapolis. Palmer (2) found in Detroit that rainfall intensities in excess of

TABLE II.—Sewer Overflow Frequency

Interceptor Capacity (× DWF)	Number of Overflows per Month		
	McKee	Palmer	Johnson
2	5.6	7.2	5.6
3	5.0	6.7	5.0
5	4.2	6.0	4.3
10	3.2	—	3.2

0.04 in./hr will occur about 2.5 per cent of the total time. Shifrin and Horner (5), at St. Louis, found that with an interceptor capacity of 1.36 × DWF, 3.07 per cent of all sanitary sewage will escape and with an interceptor capacity of 2 × DWF, 2.19 per cent of the sewage will escape. For St. Louis, 1.36 × DWF represents peak sanitary flow.

These data indicate that: (*a*) with an interceptor capacity designed at 2 to 3 × DWF, about 2 per cent of all the sanitary sewage escapes, and (*b*) this occurs during only 2 to 6 per cent of the time. Increasing the interceptor capacity from 2 to 5 × DWF, or 250 per cent, results in only about 1.5 per cent more sanitary sewage being treated.

Frequency of Combined Sewage Overflow

Palmer (2), Johnson (3), and McKee (4) made studies of the frequency of overflows from combined sewers. The number and frequency of these overflows is dependent on the storm intensity and the capacity of the interceptor sewer. The results of these three investigators are shown in Table II.

TABLE III.—Effect of Storm Concentration on Overflow Frequency

Interceptor Capacity (× DWF)	Number of Overflows per Month*			
	(1 hr)	(2 hr)	(3 hr)	(4 hr)
2	6.5	5.8	5.1	4.6
3	5.8	5.0	4.3	3.9
5	4.7	4.0	3.4	2.8
10	3.4	2.7	2.0	1.5

* For various times of concentration.

Camp (1) reasoned that the time of concentration in combined sewers from low intensity rainstorms can exceed 60 min for Concord, N. H. He determined the number of overflows from different interceptor capacities and different times of concentration. His results are shown in Table III.

Camp found that the Concord data indicated about the same frequency of overflows as the Boston rainfall data for large capacity interceptors.

TABLE IV.—Duration of Overflow

Interceptor Capacity (× DWF)	Per Cent of Total Time		
	McKee	Palmer	Johnson
2	5.7	2.5	—
3	3.7	2.1	2.7
5	2.2	1.5	2.1
10	1.2	—	1.1

Duration of Combined Sewage Overflow

Although overflow frequency is important, the duration of overflow must also be considered. Rainfall intensity and interceptor capacity are the principal determinants of overflow duration. Palmer (2), Johnson (3), and McKee (4) studied overflow frequency and duration for Boston, Detroit, and Washington, respectively. Their results are shown in Table IV.

Shifrin and Horner (5) found that overflows will occur about 4.9 per cent of the time at St. Louis with an inter-

TABLE V.—Average Duration of Overflows

Interceptor Capacity (× DWF)	Hours		
	McKee	Palmer	Johnson
2	7.4	2.6	—
3	5.4	2.3	4.2
5	3.8	1.8	3.6
10	2.7	—	2.6

ceptor capacity equal to the peak dry-weather flow of 1.36 × DWF.

By correlating the duration of overflow with the frequency of overflows, the average duration of each overflow in hours for the data of McKee, Palmer, and Johnson was computed with the results as shown in Table V.

Pollutional Characteristics of Storm Water and Combined Sewage

Storm Water

Palmer (2) collected and analyzed samples from a catch basin in the business district of Detroit during a rainstorm to determine the pollutional characteristics of the storm-water runoff from a separate storm sewer containing no sanitary sewage. The results of the individual analyses ranged as follows:

Coliform bacteria (MPN/100 ml)	25,000 to 930,000
Total solids (mg/l)	310 to 914
Volatile solids (mg/l)	136 to 414
5-day BOD (mg/l)	96 to 234

As would be expected, the composition of the storm sewer flow exhibited wide variations. Palmer concluded that the quality of water from separate storm sewers is very unsatisfactory when judged by the standards applied to overflows from combined sewers. Akerlindh's (7) investigation of the quality of storm-water flow reported similar BOD values.

Combined Sewage

Palmer (2) also made studies of the character of the overflow wastes from a combined sewer. His conclusions were that after the quantity of storm flow exceeds the capacity of the interceptor of 2 to 2.5 × DWF, the quality of the overflow will be approximately:

Coliform bacteria (MPN/100 ml)	4,300,000
Suspended solids (total) (mg/l)	250
Suspended solids (volatile) (mg/l)	100
5-day BOD (mg/l)	50

Plus variations of 100 per cent and minus variations of 50 per cent are to be expected. Palmer's other conclusions were: (*a*) erratic variations in the composition of combined sewage overflow are characteristic, and (*b*) a condition of more-or-less uniform quality of combined sewage overflow cannot be expected unless the storm period substantially exceeds the time of concentration, and the rainfall is of sufficient intensity to provide high velocities.

TABLE VI.—Storm Flow Characteristics at Buffalo

Item (mg/l)	Bird Ave. District		Bailey Ave. District	
	Prior to Rainstorm	During Rainstorm	Prior to Rainstorm	During Rainstorm
Total solids	498	754	461	785
Suspended solids	158	544	126	436
Volatile susp. solids	108	350	92	196
5-day BOD	162	100	127	121

Riis-Carstensen (8) reported on an extensive program of gaging and sampling of the flow in combined sewers at Buffalo, New York. In two districts before and during a 0.55 in. rain, the characteristics of the wastewater changed as shown in Table VI.

Suspended solids in samples ranged from 172 to 1,220 mg/l during the storm period in the Bird Avenue District. Riis-Carstensen computed that in one hour during the storm the combined sewage carried 28.4 times the normal amount of suspended solids. He concluded that the strength of the overflow varied widely and that any evaluation of the pollutional effect of combined sewage overflows based on volume only, may be grossly misleading.

Interceptor Costs

The quantity of the combined flow intercepted will determine the size of the interceptors required to carry the

TABLE VII.—Interceptor Capacity and Cost

Interceptor Capacity (× DWF)	Sanitary Sewage Lost by Overflow (%)	Selected Pipe Size (in.)	Relative Interceptor Cost (% of Base)
1.5 (Base)	—	36	100
2	2	42	123
3	—	48	149
4	—	54	179
5	1	60	214

flow to the sewage treatment plant. The greater the quantity intercepted, the larger is the sewer size required and the greater the cost. A study was made to determine the relative sewer costs when varying quantities are intercepted. The assumptions were: A minimum capacity equal to the peak dry-weather flow of 1.5 times the average dry-weather flow is required in every case and is therefore the base; $n = 0.013$; 36-in. pipe with a velocity of 2 fps when flowing full for basic capacity and costs; the same grade for all sizes of sewer; and only the pipe and trenching costs are considered. Based on these assumptions, the interceptor size and relative costs for interception of various flows are shown in Table VII.

To reduce the quantity of sewage lost by overflow from approximately 2 per cent with an interceptor capacity of 2 × DWF, to approximately 1 per cent with an interceptor capacity of 5 × DWF, or a reduction of 1 per cent, the interceptor cost would be nearly doubled. The small reduction in sewage lost to the receiving stream obtained by increasing the interceptor capacity by 2.5 times does not appear to justify the resulting large increase in interceptor cost.

Analysis of Rainfall and Runoff in Kansas City, Mo.

A detailed study was made of rainfall frequency and intensity for the Kansas City, Missouri, area. The data selected for analysis were the official published records of the U. S. Weather Bureau, entitled "Hourly Precipitation," for the Municipal Airport Station, Kansas City, Missouri. The period chosen was March to November, from 1950 through 1959. It was reasoned that precipitation during the winter months of December, January, and February probably would occur as snow, thus complicating the studies of runoff. These three months were, therefore, excluded from the study. The frequency of occurrence of various rainfall intensities was determined by counting the number of hours during which each intensity occurred. For ease of computation and analysis, the rainfall intensities were grouped. Results of the computations are presented in Figure 1. Center-of-strip plotting was employed. From this figure it can be seen that measurable rainfall occurs only about 5 per cent of the time at Kansas City during the March through November period.

Several assumptions were made to compute the runoff. These assumptions were: (*a*) the first 0.04 in. of rainfall would be needed to wet down the area before runoff begins, (*b*) runoff from impervious areas would be 100 per cent after initial wet-down, (*c*) runoff from previous areas would be the rainfall rate in excess of an assumed infiltration rate into the soil of 0.10 in./hr, and (*d*) the area was considered to be 50 per cent impervious and 50 per cent pervious. This last assumption was based on 1945 studies of the Kansas City sewerage system.

Deducting the first 0.04 in. at the beginning of each storm for surface wetting, the frequencies of occurrence of rainfall of various intensities were recomputed. The results are shown in Figure 2. The analysis shows that rainstorms producing runoff occur only about 3.7 per cent of the time at Kansas City during the March through November period.

The runoff from the adjusted rainfall was then computed using the above

assumptions. The runoff, expressed as in./hr (equivalent to cfs per acre), is also shown in Figure 2. The 1958 report on trunk sewers and sewage treatment facilities for Kansas City estimated that the 1957 average annual dry-weather flow of sanitary sewage was approximately 0.0035 cfs per acre or 0.0035 in./hr. Using this figure for average dry-weather flow, Figure 2 shows that runoff of $1 \times$ DWF or greater will occur 3.55 per cent of the time and that runoff of $2 \times$ DWF or greater will occur 3.22 per cent of the time.

Removal of Pollutants at Kansas City, Mo.

With the peak dry-weather flow for Kansas City of 1.5 times the average

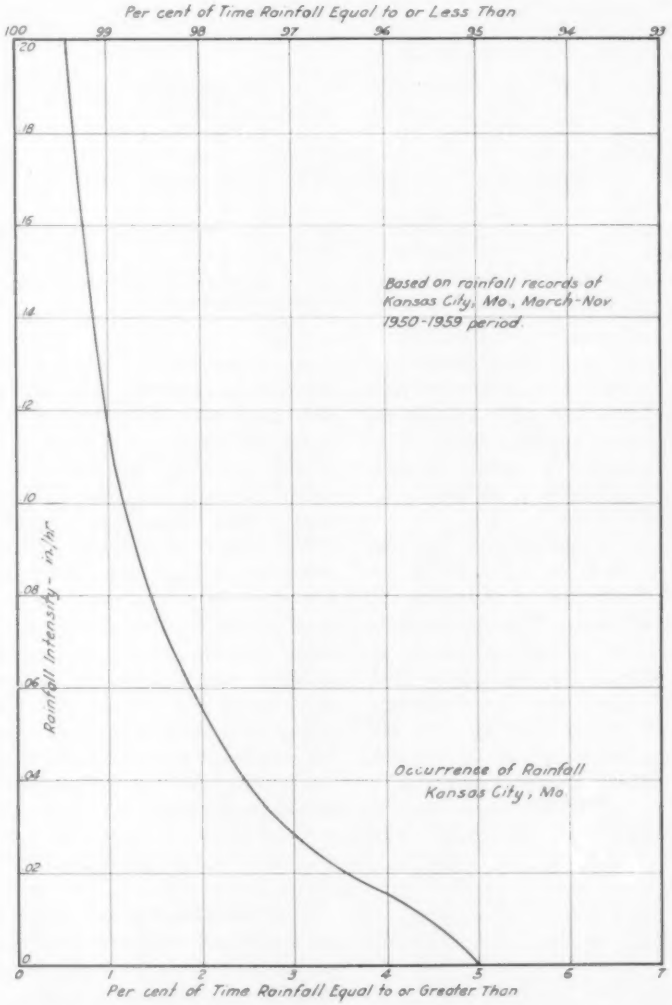

FIGURE 1.—Analysis of rainfall for Kansas City, Mo., during March through November for period of 1950–59.

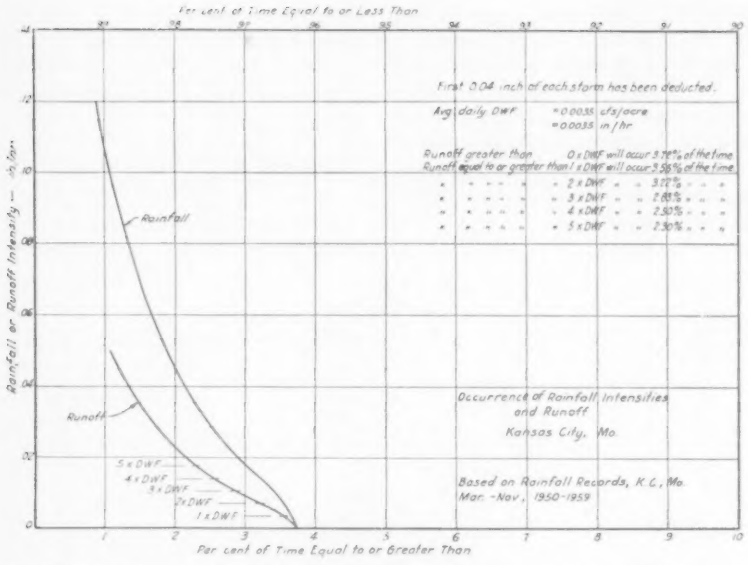
Per cent of Time Equal to or Less Than
First 0.04 inch of each storm has been deducted.
Avg daily DWF =0.0035 cfs/acre
=0.0035 in/hr
Runoff greater than 0 x DWF will occur 9.78% of the time
Runoff equal to or greater than 1 x DWF will occur 5.56% of the time
2 x DWF = 3.72%
3 x DWF = 2.83%
4 x DWF = 2.30%
5 x DWF = 2.30%
Rainfall
Runoff
Occurrence of Rainfall Intensities and Runoff
Kansas City, Mo.
Based on Rainfall Records, K.C., Mo.
Mar. - Nov., 1950-1959
5 x DWF
4 x DWF
3 x DWF
2 x DWF
1 x DWF
Rainfall or Runoff Intensity — in./hr.
Per cent of Time Equal to or Greater Than

FIGURE 2.—Analysis of rainfall and runoff for Kansas City, Mo., during March through November for period of 1950–59.

dry-weather flow and if an interceptor capacity is selected to carry the peak dry-weather flow plus a certain amount of storm-water runoff, Table VIII shows the relative frequency of overflow to be expected with various interceptor capacities.

Increasing the interceptor capacity from 1.5 × DWF to 3.5 × DFW reduces the frequency of overflow by only 0.50 per cent. The reduction in loss of sanitary sewage would be of the same order. An interceptor with capacity to carry only the peak dry-weather flow would overflow 3.72 per cent of the total time, and one with capacity to carry the peak dry-weather flow plus storm-water runoff equal to twice the average dry-weather flow, would overflow 3.22 per cent of the time. As shown in Table VII, an interceptor with capacity to carry 3.5 × DWF would cost about 1.5 times as much as an interceptor with capacity to carry only the peak dry-weather flow. This is especially important in large communities where large and expensive interceptors are required to carry peak dry-weather flow. Significantly increasing these costs would not be justified, considering the extremely small reduction in overflow time which would be obtained.

TABLE VIII.—Frequency of Overflows Expected

Interceptor Capacity (× DWF)	Allowance for Storm Water (× DWF)	Overflow Occurrence (% of time)
1.5	0	3.72
2.5	1	3.55
3.5	2	3.22
4.5	3	2.83
5.5	4	2.50
6.5	5	2.30

Summary

1. A number of independent investigators of combined sewer overflows reported general agreement as to: (*a*) rainfall required to produce runoff, (*b*) sanitary sewage overflow with various interceptor capacities, and (*c*) fre-

quency and duration of overflows with various interceptor capacities.

2. Because storm-water flows are so much greater than the sewage flow in any combined sewer, all investigations of how much capacity should be provided in an interceptor sewer have invariably reached the conclusion that the practical maximum effective capacity is not appreciably greater than the peak dry-weather flow. This practical maximum effective capacity is about 1.5 times the peak dry-weather flow.

3. Since interceptors must be capable of carrying at least the peak dry-weather flow it would be logical to express the required interceptor capacity in terms of the peak dry-weather flow. This would allow comparison of interception ratios regardless of the size of the communities involved.

4. Little is known about the pollutional characteristics of storm-water runoff, particularly from urban areas. Information is needed on how these characteristics vary (*a*) from city to city, (*b*) with intensity of storm, and (*c*) with duration of storm. Comparative data on runoff from suburban and rural areas would also be valuable.

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HELP!

In addition to the busy holiday season this is the time when membership renewals must be processed. To make sure all renewals are completed correctly in the proper time we need your help. You may perform this help by forwarding your 1962 dues to your **Member Association Secretary** before the Christmas rush.

This will provide enough time for your Secretary to process the dues and forward the renewal list to us. These must be handled before February to assure uninterrupted delivery of the Journal. Reinstatements mean delays.

Thank you for your cooperation. If you have not received your notice your Secretary is listed on page 670a.

SEWAGE TREATMENT BY EXTENDED AERATION

R. Porges, G. L. Morris, W. W. Towne, E. J. Struzeski, Jr., and G. L. Harlow

In recent years a nation-wide population upsurge has been accompanied by an extensive development of suburbs. The building of housing developments, shopping centers, motels, schools, industries, and other services has greatly exceeded the construction of interceptor sewers to central metropolitan sewage treatment works, and interim or permanent isolated facilities have become necessary. At the same time, local sewerage systems have been favored over on-lot disposal as an answer to the immediate problem.

Conventional types of waste treatment plants have been designed for small installations and have proved satisfactory. Septic tanks, with subsequent subsurface disposal, gravel beds or sand filters, have been utilized in many instances with success depending on soil characteristics. Waste stabilization ponds have been used effectively for interim and permanent waste treatment where suitable land is available for the acreage required.

During the last ten years a modification of the activated sludge process, "extended aeration," has rapidly gained in use for treatment of sewage (Figure 1). The application of the process consists of an aeration tank providing for a detention time much longer than conventional activated sludge, which is followed by a settling tank of several hours detention, for separation of liquid and sludge. The supernatant liquor is discharged as plant effluent and the settled sludge is returned to the aeration unit. The design relies on the stabilization of organic matter under aerobic conditions, with disposal of the end products through the air as gases, by passage in finely suspended or soluble form in the effluent liquor, or by sludge wastage. In this system the conventional activated sludge process is simplified by elimination of the primary settling tank and the anaerobic sludge digester.

The extended aeration type plant is a new tool in the series of waste treatment devices. In recent years hundreds of these plants have been placed in operation. The rapidity of this growth has outdistanced orderly compilation of data concerning their applicability and effectiveness. At the same time, increasing state interest has stimulated requests by the Conference of State Sanitary Engineers and the Great Lakes-Upper Mississippi River Board of Sanitary Engineers to the Public Health Service for an evaluation of these and other types of small sewage treatment plants. This report is directed to the preliminary evaluation of extended aeration under field conditions as reported by the states (1), and is limited to plants in the range of 20 to 2,500 population equivalents in terms of 5-day BOD. No testing of plants or experiments with the process was possible in this study.

Accumulation of Data

Regional offices of the Public Health Service were asked to obtain from each

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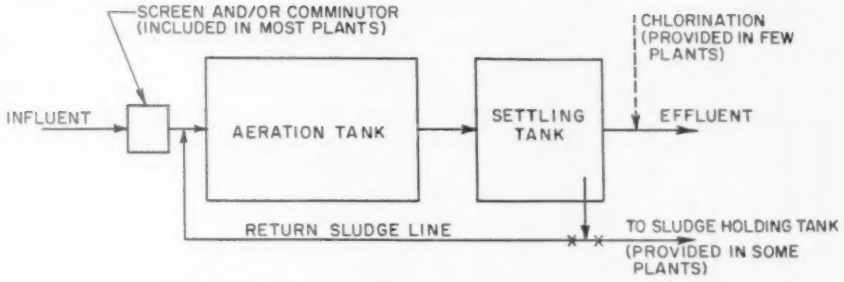

FIGURE 1.—Flow diagram of extended aeration process.

of the 50 states data on the number of current plants and installations served, laboratory records available, state requirements, and state experiences and reactions. In 11 states having many plants, staff members of this project contacted the state health departments directly and visited plants in person to obtain additional information from state engineers and plant operators, to observe on-site plant operation, and to discuss the various features of the extended aeration plants.

Numbers in Service

Data obtained from the states show that as of July 1, 1960, there were 1,224 small extended aeration plants in service or under construction distributed geographically as illustrated in Figure 2. Extended aeration plants have been used primarily to serve installations where daily sewage volumes are small. For example, Ohio reports 64 per cent of the 399 small plants in that state are in the 2,000–to 15,000-gal range (Figure 3). Figure 3 also shows that

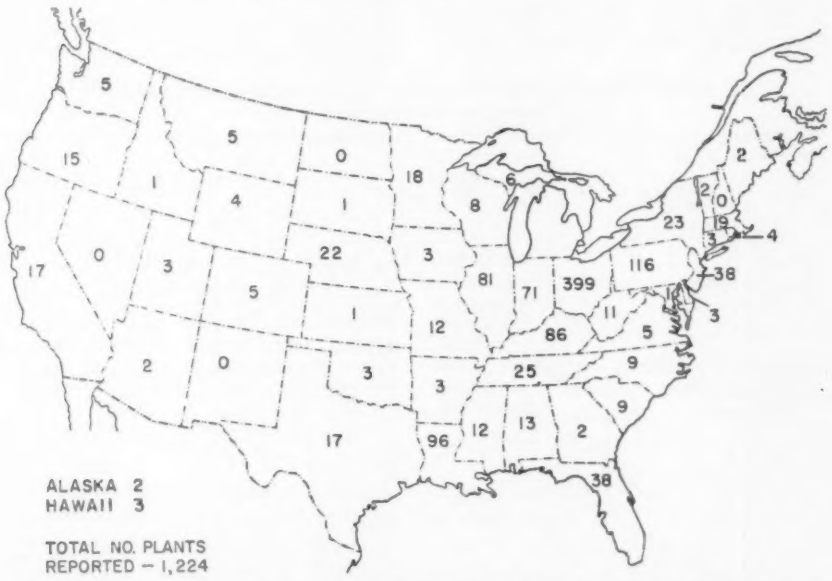

FIGURE 2.—Distribution of extended aeration plants throughout the United States (from a 1960 survey).

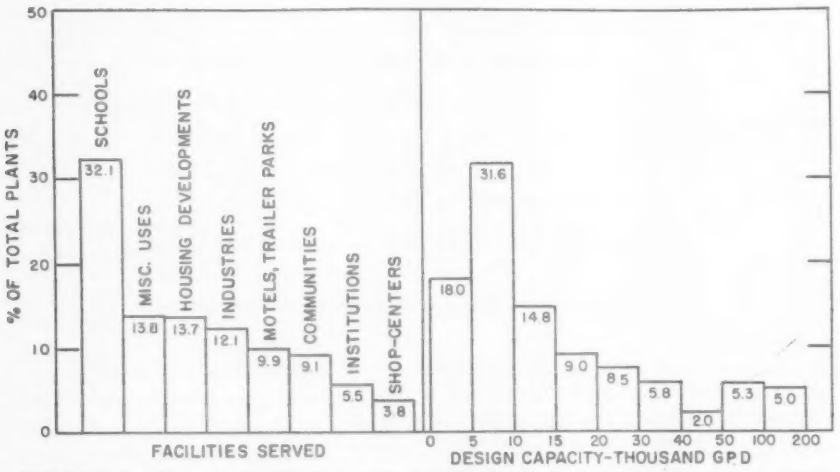

FIGURE 3.—Use of classification and size distribution of extended aeration plants. Data in left half of figure are from 1,224 reported plants. Data in right half are from 399 Ohio plants.

schools are the greatest users of extended aeration plants with 32 per cent, followed by housing developments, and miscellaneous uses with approximately 14 per cent each.

Analytical Data

Laboratory data from 59 of the 1,224 plants form the basis of the performance evaluation (Table I). Composite samples collected from individual plants ranged from 1 to 37 in number. The duration of collection varied from 3 to 24 hr. The 59 plants taken as a group provided an average 5-day BOD removal of 86.5 per cent, with a median of 91.5 per cent. Maximum and minimum BOD removals

TABLE I.—Summary of Results Obtained from Laboratory Analyses from Extended Aeration Plants

Type of Facility Served	No.	Design Flow Range (gpd)	No.	Actual Flow Per Cent of Design		Avg 5-day BOD Removals (per cent)	Avg Suspended Solids Removals (per cent)
				Range	Avg		
Schools	18	4,700–63,000	15	20.3–103.7	39.6	87.1	60.3
Housing developments	7	15,000–100,000	7	16.8–105.0	57.3	91.6	69.4
Industry	7	6,900–100,000	6	31.2–131.5	79.7	88.1	62.7
Community	5	15,000–120,000	5	28.3–115.3	69.6	89.2	76.2
Institution	3	7,000–40,000	3	66.3–128.6	91.8	94.7	83.2
Motels, trailer parks	6	2,500–25,000	4	38.7–152.0	81.7	74.9	46.5
Shopping center	8	12,000–100,000	8	20.0–145.6	78.0	94.0	65.9
Miscellaneous	5	8,500–21,400	2	24.4– 38.8	31.6	75.5	43.1
Total	59	—	50	—	—	—	—
—	—	—	—	—	—	87.0*	62.1*
—	—	—	—	—	—	91.6†	73.0†
—	—	—	—	—	—	99.3‡	96.5‡
—	—	—	—	—	—	33.3§	00.0§

* Avg of total plants (59).
† Median of total plants.
‡ Maximum of total plants.
§ Minimum of total plants.

were 99.3 and 33.3 per cent, respectively. The suspended solids removals averaged 62.2 per cent, with a median of 75.2 per cent. A maximum daily suspended solids removal of 96.5 per cent was reported by one plant, whereas in six plants the suspended solids content of the effluent remained essentially the same as the raw sewage or increased to a concentration higher than the raw sewage.

Costs

Data on initial estimated construction costs were obtained for 47 plants. Cost values were adjusted to June 1960 on the basis of the construction cost index (2). The estimated construction cost varied from \$0.34 to \$4.31 per gallon of design capacity. The design capacity varied from 3,000 to 250,000 gpd. Final construction cost data were obtained for 13 plants with design flows less than 40,000 gpd. The construction cost ranged from \$1.05 to \$2.77 per gallon of daily design flow.

There are indications that the cost for plants in the range of 40,000- to 90,000-gpd design flow will approximate \$1.00 per gallon. Larger plants will probably show decreasing unit costs per gallon with increased design flow.

The average plant power cost reported for 14 extended aeration plants, excluding lift stations, approximated \$1,410 per year. Power costs in terms of a unit volume of flow indicated average and median costs of \$111.20 and \$104.10, respectively, for each million gallons of actual waste treated.

Maintenance Time

The average amount of operation and maintenance attention given small extended aeration plants is 12.7 man-hr per week, based on information from 52 plants. The time range for these plants was 1 to 47 man-hr per week. The figures support the general impression obtained from operators that these plants need daily attention of one or two hours plus additional time for overhauling and replacement of equipment. Because of inadequate attention approximately 10 per cent of the plants visited were by-passing raw sewage and others obviously were performing poorly.

Plant Location

Reported data indicate the variability of plant location. Properly designed and operated extended aeration plants have been constructed in close proximity to inhabited areas without noticeable odor nuisance. One such plant was built with the side walls completely above ground level and located in a large parking lot serving a shopping center. Another plant located near a swimming pool at a luxurious motel was landscaped from view and caused no noticeable odor. Conversely, the prevalence of objectionable odors from a plant constructed in the basement of a building indicates that sewage treatment plants should be located in areas outside of inhabited buildings.

Design Requirements

Fourteen states reported design requirements or recommendations on the aeration unit. Most states specified 24 hr aeration time based on total daily flow. One state requires 30 hr aeration time.

Fourteen states reported design requirements on the settling tank. A detention time of four hours based on average daily flow was most frequently mentioned. Runoff periods of 8, 12, 16, and 24 hr, depending on the type of facility served, are used in some states to determine settling tank capacity.

Eleven states reported that sludge holding tanks were required or requested in the plant design. The tank design capacity ranged from 2 to 8 cu ft per capita. Consideration of a sludge holding tank in plant design is

very pertinent. Some states insist that sludge holding capacity is essential; whereas, others do not. The present study cannot properly evaluate the role that sludge holding tanks play in over-all treatment, but the specific information thus far obtained from state health departments and from special studies on particular types of extended aeration plants is worthy of note.

The Ohio Department of Health recommends sludge holding tanks in those plants where aeration is by diffused air from blowers, and they are required when mechanical aerators are used. The State of Kentucky requires sludge storage where flows are greater than 25,000 gpd; whereas, Indiana requires it where flows are greater than 100,000 gpd. Wisconsin requires sludge holding tanks in all plants, and Illinois specifies that storage shall be used where necessary or desirable. Seven states are guided by Ohio design criteria for extended aeration plants and presumably adhere to Ohio requirements on sludge holding. The remaining states did not express any views on the subject. A report (3) states: "If an exceptionally high degree of treatment in terms of suspended solids is required, a sludge holding tank should be incorporated in the design."

Of the 53 plants visited, 32 were equipped with sludge holding tanks. In order to produce consistently good BOD and suspended solids removal, wasting of sludge from the system appears necessary. Where the carry-over of partially oxidized solids in the plant effluent to the receiving watercourse is permissible, a sludge holding tank may not be necessary. Some states regard stabilization ponds or sand filters as sufficient control to prevent excess solids from reaching a watercourse. Of 73 plants that reported on the type receiving stream, 23 were discharging to dry ditches and 50 to all-weather watercourses.

Some control is desirable over the ultimate disposal of the sludge trucked from the plant. The perpetual question is where to put it. In Dade County, Florida, a commercial plant was constructed to handle this type sludge and materials from septic tanks or other sewage treatment installations. The sludge was given an additional seven days' digestion under anaerobic conditions, following which it was dewatered on sand beds. This concept of a special plant for handling of sludge is one solution to the sludge disposal problem for a group of small sewage treatment plants.

Loadings and Operation

The extended aeration sewage treatment plant can be used successfully over a considerable range of loadings and flows. As with any treatment process, extreme variations above design capacities will reduce treatment efficiencies. The extended aeration plant can be designed to provide high BOD removal if adequate operation and maintenance are assured.

This study did not concern itself with the use of these plants in the treatment of wastes other than sewage. However, several plant operators and state representatives indicated that operating difficulties might be expected with plants receiving a significant proportion of laundry or restaurant wastes. They recommend that sewage plants serving shopping centers or heavily developed commercial areas be protected by requiring grocery stores and similar establishments to dispose of vegetable wastes by garbage collection rather than by discharge to the sanitary sewer.

One of the characteristics of the extended aeration treatment process is discharge of the end products of aerobic digestion, other than gases, by way of the effluent. These materials are frequently detected by increases in volatile and suspended solids in the effluent even though the 5-day BOD may be low.

Summary

A summary of state requirements indicates the majority of the states require the ownership and the responsibility for operation and maintenance of sewage treatment plants be placed in an official body or legal entity, such as sewer districts, municipalities, and tax supported agencies. Private trusts, companies, or corporations may satisfy the "official body" requirement when licensed by the state utilities commission. In an effort to insure efficient and reliable operation of such facilities, one state (Florida) requires the manufacturers to post a performance bond; and another state (Texas) limits approval to plants that have local personnel and other resources necessary to supply operation and maintenance services.

The rapid growth of small sewage treatment plants is placing an enormous burden on regulatory agencies. To ensure full-time, effective operation there should be frequent routine inspection of all small plants. The 1,224 extended aeration plants and many other conventional small plants, imposes a tremendous field inspection load. Continuous good operation of waste treatment plants is a major factor in the reduction of the pollution load on the U. S. stream network.

Conclusions

1. The data on extended aeration plants collected during this study are insufficient in both extent and detail to adequately evaluate the factors controlling construction and operational costs, design criteria, and those affecting the performance of such plants. However, certain trends in current practice can be detected.

2. Extended aeration plants for treatment of sewage are receiving wide usage for both permanent and temporary installations. These plants can be designed and operated to produce high BOD removal efficiencies.

3. One of the outstanding operational features of extended aeration plants in the absence of noticeable odors.

4. Wide differences of opinion exist concerning the need for sludge wasting facilities and the attendant sludge handling and disposal problems. It is generally recognized that withdrawal of activated sludge will enhance effluent quality; therefore, the necessity for such facilities will be governed by the quality of effluent required for the particular receiving stream.

5. There is a paucity of data concerning the fate of the aerobically digested sludge as well as the significance of the relationship between the BOD, suspended and volatile solids in plant effluents, and their effect on the receiving stream.

6. Operating difficulties might be expected with plants receiving a significant proportion of laundry, restaurant, or supermarket wastes. Several states recommended that grocery stores and similar establishments be required to dispose of raw vegetable wastes by garbage collection rather than by discharge to the sanitary sewer.

7. Each plant should be designed so as to incorporate basic devices such as a flume and stilling well in which flow measurement equipment can be installed. In relatively large plants permanent flow measurement devices and totalizing instruments should be part of the design features. Absence of an electric power meter in most plants impaired the study of operation costs.

8. There is a wide range of opinion concerning the minimum time necessary for the operator to spend at the plant to provide proper operation and maintenance. There are certain housekeeping chores that require attendance on a daily basis. It appears that one hour per day for routine work is the absolute minimum to secure reasonable results in the smaller plants. Addi-

tional time will be necessary for plant breakdowns or emergencies. Larger plants require more time.

9. While it is realized that firm design criteria are not well established; this process, as any other sewage treatment process, requires the application of the principles of engineering evaluation.

10. Simplicity of process, flexibility of units, small site requirements, and ease of architectural treatment make these plants adaptable to many locations.

Acknowledgments

The assistance of sanitary engineers in the state health departments, state water pollution control agencies, and the Public Health Service regional offices, by securing data and information in the 50 states, is gratefully acknowledged.

Also recognized is the help obtained from manufacturers, local health personnel, and plant operators in providing information.

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LONDON MEETING PLANS PROGRESSING

Plans for the International Conference on Water Pollution Research to be held in London next September 3–7 are progressing on schedule.

The Federation as the principal sponsor is happy to report that financial support from the Division of Water Supply and Pollution Control of the Public Health Service in the form of a research grant now has been given.

The program is complete and will be reported in the January JOURNAL. Abstracts of the papers will appear in the March JOURNAL.

Attractive charter flight arrangements are essentially assured. Further information will be mailed soon to those who already have indicated interest. If you wish to attend the meeting and have not been in touch with the travel committee you are urged to make inquiry immediately to learn whether charter space is still available. Contact Thomas P. Quirk, Malcolm Pirnie Engineers, 25 W. 43rd St., New York 36; or the Federation office.

THE THERMAL POLLUTION PROBLEM

Richard D. Hoak

The possibility that stream temperatures may have to be controlled by regulating the discharge of heated wastewater has excited a fair amount of discussion in recent years, especially among aquatic biologists. Temperature is a very important factor in the aquatic environment because, per se, it can determine the species that will live and reproduce in a given body of water. In addition, it governs a number of interdependent factors that affect aquatic organisms, such as the concentrations of dissolved oxygen, carbon dioxide, pH, toxicity, and the physical activity of fish. Thus, in streams where fish propagation is a significant consideration, the effects of discharging hot water cannot be neglected.

The proponents of stream-temperature regulation aver that conservation of fish habitats would be only one of the desirable results. They argue that there would also be large benefits to industry and public water supplies. Inasmuch as some 80 per cent of the industrial intake of water is used for cooling, it would seem plausible to assume that cooler raw water would confer a real benefit. In actual fact, however, among the various factors that influence successful manufacturing, cool water occupies a minor place and industry does not object to using warmer water than it would prefer. Industry resorts to well water or refrigeration where water must be cooler than the raw supply. In municipal water treatment plants, the lower the temperature of the water entering the plant, the more difficult the treatment becomes, and for each 10°F rise in water temperature the cost of chemicals is lowered by 30 to 50 cents per million gallons treated. On the other hand, warm water may promote the growth of algae that cause taste and odor in the finished water. The good and bad features of cool water for domestic supply are therefore in approximate balance. For these reasons, this discussion of temperature control will be limited to effects on fishing.

Richard D. Hoak is a Senior Fellow, Mellon Institute, Pittsburgh, Pa.

The paper was presented at the Annual Meeting of the Pennsylvania Water Pollution Control Association in University Park, Pa., Aug. 10–12, 1960. Certain data have been added to the original paper as a result of later developments.

Recreation Increase

The recreation industry has been expanding rapidly, in step with an increasing standard of living which is providing more and more leisure for the enjoyment of outdoor activities. And those who seek relief from the stress of modern living have found that the therapeutic value of fishing can hardly be overestimated. The extent to which people are turning to fishing for recreation is revealed in a report to the Senate Select Committee on National Water Resources (1). Data for 1954, and projections for 1980 and 2000, are given for the nation in Table I.

The figures in Table I are impres-

TABLE I.—Estimates of Recreational Fishing

Year	No. of Fishermen (1,000)	Man-Days of Fishing (1,000)	Expenditure ($1,000)
1954	20,813	397,447	1,914,292
1980	46,518	930,379	4,481,144
2000	62,613	1,299,102	6,257,087

TABLE II. Value of an Acre-Foot of Water

Use	Mean ($)	Maximum ($)
Domestic	100.19	235.66
Industrial	40.73	163.35
Irrigation	1.67	27.04
Hydropower	0.71	5.90
Waste disposal	0.63	2.56
Inland navigation	0.05	1.17
Commercial fisheries	0.025	1.06

sive, and they suggest the magnitude of the public demand being generated for improvement of fishing everywhere. The report cited (1) is almost impassioned in its recitation of the minor role to which fish and wildlife conservation has been relegated by flood control, navigation, irrigation, hydropower, and industry in the development of water resources. Fish and wildlife, the report states, are largely values of the mind, the heart, and the spirit—values not readily measurable in dollar terms. The report complains that there are people who would divide all water resources among those who can best use them for profit in industry and agriculture.

Mutual Exclusiveness of Water Uses

In any locality there are normally several competing uses for surface water, and these are sometimes mutually exclusive. There is universal agreement that the highest priority of water use is for the public water supply. Among the other uses, however, there can be no agreement on priorities in any broad sense because of the relative importance of the several water uses between different areas with varied local interests. The industrial economy of the United States has created a standard of living that allows its citizens great freedom to enjoy the varied pleasures of outdoor recreation. But this does not necessarily mean that all streams must afford recreational opportunities. A major virtue of fishing as a strain-relieving activity lies in the fact that it takes the participant away from the bustle of the city and the sight of industrial plants. Many fishermen in the East are strangely unhappy if they must drive more than a few miles to wet a line and catch a fish. In western Texas, a semi-arid region, people do not mind hauling their outboards 200 or 300 miles for a day's sport on the water.

Valuation of Water Uses

One legitimate function of streams is to carry off wastewater to the extent that it does not unreasonably impair other stream uses. Practically every use of water impairs its value for other purposes to some degree, and there are frequent disputes over the reasonableness of the impairment. These disputes are difficult to resolve because there is rarely a quantitative basis for comparing the value of several uses in terms of the broad public interest. Renshaw (2) attempted to compare a number of uses by computing "... the maximum amount people would be willing to pay for the use of water in any amount or direction rather than forego the amount or use entirely." His figures are given in Table II.

The figures in Table II are gross values which include the various costs incident to the preparation and delivery of water. It shows that domestic and industrial uses are by far the most valuable, and that there is a large dollar-gap between these and the others for which values were calculated. It is interesting to see where sport fishing might rank in this kind of monetary evaluation. The Fish and Wildlife Service has estimated (1) the present (1954) and future water requirements for sport fishing, in terms of acre-feet of water. By dividing these estimated requirements into the projected expenditures of Table I, it appears that the fishing-sports value of an acre-foot of water approximates $21.50, $23.13, and $24.68 for 1954, 1980, and 2000, respectively. Although

fishing enthusiasts claim that it is improper to place a dollar-value on their sport, it is obvious that they are willing to spend substantial sums to engage in it.

Proposed Temperature Regulations

There are many activities of mankind that have both immediate and long-term effects on fishing, but this paper is concerned primarily with the consequences of discharging heated wastewater. A few streams that drain heavily industrialized areas have temperatures that are normally higher than desirable; such streams rarely support any fish life. Elsewhere, fish kills have resulted from the sudden discharge of a quantity of hot water. In general, however, those who would control stream temperatures are concerned chiefly about the effects of an anticipated steady increase in thermal loads. The steam-electric power industry is often cited to illustrate the prospective danger of thermal loading because the installed capacity of that industry tends to double every decade.

Several states have regulations which directly or indirectly cover temperature control but these rules are limited in scope. Looking to the future, the Pennsylvania Department of Health proposed a set of specific regulations to govern the discharge of heated wastewater. These regulations were advanced to furnish a basis for discussions that would lead to practical temperature controls. The proposals were:

1. Heated discharges to the waters of the Commonwealth shall at no time or at any place raise the temperature of such waters above 93° Fahrenheit during the months of May through November, or above 73° Fahrenheit during the months of December through April, nor shall the temperature be raised at all in streams suitable for trout propagation.

2. The increased heat content caused by an industrial or other process in liquid discharges shall be reduced by at least 35% for streams requiring "primary" treatment; by an intermediate degree, to be determined by the circumstances in each case, for streams requiring "intermediate" treatment; and by at least 85% for streams requiring "complete" treatment—except that in no case shall the temperature of any discharge be required to be reduced below the average temperature of the receiving stream above such discharge.

3. In order to allow fish and other aquatic life to move freely both up and down stream, a fishway shall be constantly maintained in any stream receiving heated discharges, within which the temperature of the water shall not be raised. The average width of this stretch shall be not less than ¼ that of the average width of the stream in the affected zone, and the flow shall be not less than ¼ that of the receiving stream just above the point of waste discharge. Moreover, this stretch shall extend from above the point of waste discharge to the location at which the stream returns to normal temperatures.

4. Exception to the foregoing may be made for estuarial waters, where currents are variable and uncertain.

5. The proportion of the stream which will be allocated to any given user shall be determined by the Sanitary Water Board based on the present and anticipated future use and condition of that stream or receiving body of water.

These proposed regulations, which were intended for uniform application on a statewide basis, encountered considerable criticism, especially from industry. An Advisory Committee on Stream Temperature Control was therefore appointed to study the effects of heated wastewater discharges, and to recommend whatever regulations the investigation indicated to be appropriate. The members of the committee represented the various interests concerned with temperature regulation, but there were no representatives from the legal profession nor from the Pennsylvania Department of Commerce. G. E. Arnold, Chairman, appointed subcommittees from time to time to study particular aspects of the problem, and the Committee met with staff members of the Division of Sanitary Engineering

about once a month from September 1959 to April 1961 to discuss its findings. The Committee presented its report to the Sanitary Water Board in May 1961 and the substance of its recommendations was adopted officially in August 1961. The following discussion represents the author's interpretation of the Committee's studies; it is not a Committee report.

Are Proposed Maximum Limits Valid?

The 93°F limitation was proposed by the Aquatic Life Advisory Committee of the Ohio River Valley Water Sanitation Commission. It was selected from a review of the literature as the maximum temperature that would support a harvestable fish crop. It may be doubted that the public interest would be properly served by a regulation aimed at providing a harvestable fish crop in all streams. But aside from the question of economics, there is evidence that 93°F is an unrealistically low temperature for warm-water species. A research project (3) on the Delaware River has shown that the maximum lethal temperature for most warm-water fish may be 104°F. In fact, small-mouth bass struck at lures cast into 104°F lagoon water. Aquatic biologists admit that this may be true under certain conditions, but they claim that fish do not propagate at temperatures above 80°F. On the other hand, where condenser cooling water has been discharged into lagoons and shallow lakes in southern states for many years, no diminution in the fish population has been observed, even though temperatures range up to 97°F.

Aquatic biologists claim that a sudden rise in water temperature is quickly lethal to fish; a temperature rise of 10°F in 10 min is said to be the maximum change that can be tolerated. A California study (4) reported that yearling salmon (1.3 to 2.4 in.) could be taken from a holding tank at 55°F and dropped into flume water at 80°F without loss of life, and that the maximum temperature tolerance was 83°F. The same species could pass through power plant condenser cooling coils without ill effect. This point has been raised because it has been claimed that slugs of hot water may kill fish. Slugs of hot water are not ordinarily discharged by industrial plants; changes in operating rates normally occur gradually, and there is a corresponding slow change in the temperature of the wastewater.

An unexpected result from temperature surveys has been the finding that fishermen like warm-water discharges. The area below the Martin's Creek power plant on the Delaware River has become a wintertime fishermen's paradise. Trembley (3) reported that he and an associate caught 100 fish in one hour during a blinding snowstorm in February. The same approval of fishermen is found in the southern states where warm water greatly improves winter fishing. Chance reports (5) that fish tend to concentrate in warm waters in winter and spring. He states that these waters may serve usefully as refuges for easily winter-killed fish such as the threadfin shad. There is an indication that some species spawned earlier in the warmer water (10°F warmer) than in the lake proper. Little difference was noted in plankton production inside and outside the warm-water area.

Limiting values for factors harmful to fish are usually determined under carefully controlled laboratory conditions that may bear no relationship to natural environments. But so many variables are encountered in natural streams that laboratory techniques must be used to provide suitable conditions for deriving limits with some approximation to universality. These methods are valid as long as it is recognized that the values are not absolute and that aquatic biology is

not an exact science. Conclusions must be based on statistical analysis of data and must be qualified by an appropriate confidence interval. The final test of any limiting value must be its effectiveness in maintaining a desired condition in a particular natural environment.

The Advisory Committee on Stream Temperature Control agreed to accept the 93°F limitation of the Aquatic Life Advisory Committee because it was based on expert judgment, and insufficient field data were available to support a different fiigure. The Advisory Committee pointed out, however, that it would be necessary to prescribe a mixing zone beyond which the 93°F limit would apply. This arose from the consideration that discharge of a minute stream of water above the temperature limit would constitute technical violation of a regulation that did not specify the point at which the temperature was to be measured. Thus it seemed obvious that provision would have to be made for discharges that would affect only a portion of a body of water and for a relatively short time. The variety of situations that would have to be covered by a broad definition of mixing zones led the Committee to reject as impractical all the definitions it considered. Instead, it recommended that the Sanitary Water Board prescribe the boundaries of mixing zones where they are warranted by circumstances. The Committee proposed, however, that heat artificially added to streams be limited to an amount that could not raise the total stream flow above 93°F, assuming perfect mixing at the point of discharge. This would permit calculation of the maximum allowable temperature of a discharge in terms of its volume and the stream flow rate.

Dissolved Oxygen and Temperature

Dissolved oxygen concentration is a feature of the aquatic environment that is affected both directly and indirectly by water temperature. The equilibrium concentration of dissolved oxygen is inversely proportional to temperature, and temperature influences the rate of biochemical reactions that consume oxygen. Dissolved oxygen is vital to aquatic fauna, and biologists are understandably concerned over any adverse effects that temperature might exert on the fish available in streams. Oxygen is only slightly soluble in water; the saturation concentration ranges from 10.15 mg/l at 59°F to 7.1 mg/l at 95°F. Fortunately, the rate of reaeration of water is directly proportional to the oxygen deficit; thus as the rate of consumption of oxygen increases, so does the rate at which oxygen dissolves from the atmosphere. LeBosquet and Tsivoglou (6) have reported that the rates of deoxygenation and reaeration are about equally affected by temperature, and that the maximum oxygen deficit should be substantially unchanged over a fairly wide temperature range. Also, it has been assumed that the rate of biochemical oxidation increases with temperature, but Gotaas (7) has shown that the temperature coefficient of this reaction decreases as the temperature rises. His studies indicate that the rate of the reaction reaches a maximum at about 86°F, and that the rate actually declines at temperatures above this.

Diurnal Changes in Dissolved Oxygen

Aquatic biologists correctly maintain that average values for dissolved oxygen have little meaning for specification of conditions suitable for fish propagation; it is the minimum concentration that is harmful. It has been assumed that the concentration of dissolved oxygen in streams carrying a substantial load of organic matter will fall below the danger level for fish life at night, because no oxygen is furnished by photosynthesis, and

TABLE III.—Diurnal Variation in Dissolved Oxygen

Location	Temp (°F)	DO (mg/l)	DO (% sat.)
MonongahelaR.	71.6–77.9	7.35– 8.25	84.5– 98.5
Peters Ck.	60.8–69.8	7.10– 8.80	73.7– 97.0
Allezheny R.	70.7–79.7	7.00– 8.55	79.8–105.0
Clarion R.	67.1–74.3	7.00– 8.65	78.0– 98.0
Ohio R.	79.7–81.5	7.10– 8.90	87.0–111.1
Little Beaver Ck.	67.1–74.3	6.90–11.85	77.5–128.0

aquatic plants that produce oxygen in daylight consume it in darkness. Data from a series of 24-hr surveys, made in June and July 1960, have provided some quantitative information on this question (8). Three locations were chosen for comparison of conditions between large and small streams: Monongahela River and Peters Creek at Clairton; Allegheny River and Clarion River at Foxburg; and Ohio River and Little Beaver Creek at Smiths Ferry. Samples were collected at each pair of stations every two hours, beginning in mid-afternoon, and analyzed by the Rideal-Stewart modification of the Winkler Method. Analyses were made in a mobile laboratory on the sites. Ranges of data are given in Table III.

The pollutional loading of these streams is supposed to range from moderate to heavy. Dissolved oxygen concentrations, however, were found to be appreciably higher than might have been anticipated under such conditions. The lowest concentrations occurred at night, but it may be seen that they were all well above the 5 mg/l deemed essential for fish propagation. The rise in dissolved oxygen during daylight hours is notable; the highest temperatures occurred during those periods.

Similar results were found in a series of 48-hr surveys on the Beaver River in August 1960, and March and April 1961. The river was about 700 ft wide and several feet deep at the midstream sampling point. The location was chosen to represent a biologically stable stream of medium size; the nearest point at which a substantial volume of organic material is discharged was 27 miles upstream. Except for a single value of 5.2, all DO concentrations ranged from 7.7 to 13.1 mg/l, corresponding to 60- to 160-per cent of saturation at the sampling temperature. In both sets of surveys it was notable that there was at least as much DO in warm weather as in cold.

These surveys have shown DO concentrations do not necessarily fall to low values at night in moderately polluted streams. There is no implication that low values never occur but none were found over the range of conditions covered in the surveys. The desirability of collecting actual DO data (especially at night), instead of relying on assumptions, is clearly suggested by this work.

Cooperative Temperature Surveys

The objective of the Advisory Committee was to recommend regulations that would serve the over-all public interest. In discussing the format of such regulations it became apparent that available information on the effects of discharging heated wastewater was too limited to permit drafting regulations on a quantitative basis. It was therefore decided that temperature surveys would have to be made to provide data on the volume of stream water affected by heated wastewater; the rate of dissipation of thermal loads; the possibility of using cool subsurface water for fishways; and any tendency for a cumulative effect of heated water in the streams.

A number of companies agreed to make temperature surveys during the summer and fall of 1960. The most extensive of these was undertaken by a joint committee of steel and steam-electric power companies in western Pennsylvania to cover about 100 miles of the Allegheny, Monongahela, and Ohio rivers. A preliminary survey by project personnel disclosed 18 locations at which wastewater discharges

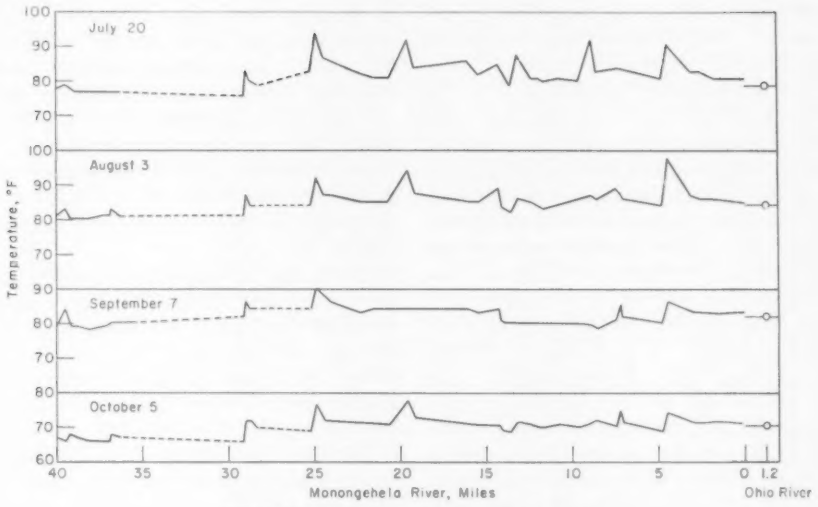

FIGURE 1.—Downstream temperatures.

caused appreciable rises in river temperatures. Temperatures were measured by trailing a sensitive thermistor 20 ft behind a motorboat running 40 to 100 ft from shore. Both banks of the three rivers were covered in the preliminary survey.

Nine survey teams were designated, each to cover two locations. All teams made their surveys on the same day, ordinarily the first Wednesday in the month, July through October, to eliminate the effects of variations in weather as much as possible. Temperatures were measured with identical calibrated indicating-thermistor instruments. The measurements were made by suspending the thermistor from a boom projecting over the side of a motorboat. The boat crossed the river at a constant speed on a line perpendicular to the shore, with the thermistor successively submerged at depths of 1, 5, 10, 15, and 20 ft. This procedure yielded data for plotting vertical isotherms. Cross sections were made upstream from a heated discharge and at intervals downstream until the temperature had fallen to a value close to that recorded at the first upstream point or until another rise was encountered.

Analysis of Survey Data

Some difficulty was encountered in arraying the survey data in a form from which valid conclusions could be drawn. Isotherms varied so greatly from location to location that any method of averaging the data would have been misleading at best. Inasmuch as temperature maxima were a primary consideration, the highest temperature recorded at each survey point was plotted against river miles. This technique afforded the most conservative interpretation of the data. Data for the Monongahela River are plotted in Figure 1 to illustrate the findings of the survey. Similar plots were made for the Allegheny and Ohio rivers but these are not included here because of the limited number of survey points and the fact that the maximum temperature found was 88°F.

The Monongahela data show that there is a fairly rapid fall in stream temperature below a heated discharge, but that the heat added at one point was not always fully dissipated be-

fore another rise in temperature occurred. The statement has been made that heated wastewater tends to raise river temperatures permanently. The survey shows that this was not true for the three rivers studied. On the right margin of the Monongahela chart is plotted the temperature of the Ohio in the back channel at Brunot Island (Mile 2.2). This channel consists entirely of Monongahela water. This temperature was one to two degrees below that at Mile 40 in three of the four surveys; in one survey (Sept. 7) it was three degrees higher. In the latter case the day began cool and foggy (7 AM), with an air temperature of 67°F. As the survey proceeded it became clear (8:55 AM) and warm (10:35 AM) and when the last run was made (1:05 PM) the air temperature was 78°F. This undoubtedly had the effect of raising the river temperature. During the preliminary survey in May 1960, it was found that the normal rise in river temperature ranged from two to four degrees from morning to afternoon, depending on the weather. Thus it may be assumed that all the heat load added artificially was completely dissipated from this river during each of the survey periods.

This analysis indicated that the rivers studied had, as a whole, ample capacity for dissipating all the artificial heat added during the survey periods.

In an effort to define mixing zones an attempt was made to derive horizontal isotherms from the vertical profiles, but it soon became obvious that this was impractical. In another approach, all temperatures of 90°F or higher were tabulated and the temperature drop per 1,000 ft was computed as shown in Table IV. Only the Monongahela had temperatures in this range.

There was appreciable variation in the rate of temperature decline. This probably resulted from differences in the rate of dispersion of the heated water and local weather conditions. The volume of river traffic would affect dispersion but there is no way to evaluate this factor. In general, the highest temperatures were close to the surface and near the point of discharge. There was only one instance where a temperature of 90°F was found more than half-way across the river. In this case, two areas of 90 to 92°F were separated by a space of about 100 ft which had a temperature of 86°F. These considerations led to the recommendation that the Sanitary Water Board fix the boundaries of mixing zones where warranted by local conditions.

One of the tentative regulations proposed by the Department of Health stated, in substance, that one-fourth of the river must not be affected at all by heated discharges, in order to provide a fishway. The survey data indicated that such a regulation, if interpreted literally, would be quite im-

TABLE IV.—Downstream Declines in Temperatures

Date	Temp. (°F)	Mile	Temp. (°F)	Mile	Drop (°F)	Distance Between Points (ft)	Temp. drop/ 1,000 ft (°F)
July 20	94	24.87	87	24.54	7	1,742	4.0
20	92	19.6	84	19.2	8	2,112	3.8
20	92	8.9	83	8.6	9	1,584	5.7
20	91	4.5	83	3.1	8	7,392	1.1
Aug. 3	92	24.87	87	24.54	5	1,742	2.9
3	94	19.6	87.5	19.2	8.5	2,112	4.0
3	98	4.5	87	3.1	11	7,392	1.5
Sept. 7	90	24.87	86	24.08	4	4,171	1.0

practical. Heated discharges, in a majority of cases, affected the entire width of the river to some extent, but the temperature rise at the bank opposite the discharge was usually only two or three degrees. The effect could be expected to be greater in turbulent streams. There must also be considered the result of heated discharges on opposite points on a river; each user would be entitled to affect up to three-quarters of the river width. Heated discharges raised temperatures at a depth of only a few feet in some cases, but in others almost the entire depth was affected. The patterns of the isotherms varied so much that no general statement could be made about the use of subsurface water for fishways. This may be only an academic question, however, because some aquatic biologists feel that a subsurface fishway would not serve the purpose. Fish kills from heated water alone are relatively rare and it would appear to be much more in the public interest to require suitable measures for protection of fish life at locations where it is evident that heated water is having a deleterious effect.

Pennsylvania Regulations

The Pennsylvania Sanitary Water Board accepted the report of its Advisory Committee on Control of Stream Temperatures in May, drafted a set of regulations in July, and released the regulations for publication in August 1960. The regulations are as follows.

1. The temperature of the waters of the Commonwealth shall not be increased artificially by amounts that shall be inimical or injurious to the public health or to animal or aquatic life or prevent the use of water for domestic, industrial or recreational purposes.

2. The heat content of discharges shall be limited to an amount that could not raise the temperature of the entire stream at the point of discharge above 93°F assuming complete mixing. The heat content of discharges may be increased or further limited where local conditions would be benefited thereby.

3. Where downstream circumstances warrant, the area in which the temperature may be artificially raised above 93°F will be prescribed.

4. A fishway will be required in streams receiving heated discharges where this is essential for the preservation of migratory pathways of game fish, or for the preservation of important aquatic life.

5. Paragraphs 2 and 3 do not apply to streams so impregnated with acid mine drainage that they cannot support a fish population typical of the region except for heated discharges which adversely affect domestic or industrial uses or secondary streams.

6. There shall be no new discharge to waters providing a suitable environment for trout if as a result the temperature of the receiving stream exceeds 58°F or stream temperature, whichever is higher.

7. Reduction of the heat content of discharges to estuarial waters will be required where necessary to protect the public interest. Estuarial waters are those containing ocean salts. Tidal waters not containing ocean salts are considered as fresh water streams.

Except for minor modifications, the above regulations are in conformance with the recommendations of the Advisory Committee. This exercise in cooperation between a regulatory agency and a representative group of technically trained individuals furnishes an example of a procedure that ought to be adopted more often in resolving difficult problems in pollution control. The fact that the deliberations covered a period of 20 months provides ample evidence that the final result was not achieved easily. Unanimous approval of the report by the members of the Advisory Committee shows that the time was well spent because, in the beginning, individual opinions were so disparate that eventual agreement appeared to be quite unlikely. The moral should be apparent.

Acknowledgment

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that has been sustained at Mellon Institute since 1938 by the American Iron and Steel Institute.

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AERATED LAGOON FOR SUBURBAN SEWAGE DISPOSAL

Ross E. McKinney and Howard Edde

In the midwest, oxidation ponds are used extensively for the treatment of domestic sewage from suburban areas. The high cost of land and a few operational problems resulting from excessive loadings have created the need for a wastewater treatment system with the operational characteristics of the oxidation pond but with the ability to treat more organic matter per unit volume.

Research at Fayette, Missouri (1) on oxidation ponds has shown that the BOD in the treated effluent varied from 30 to 53 mg/l with loadings from 8 to 120 lb BOD/day/acre. Since experience indicates that effluents from oxidation ponds do not create major problems at these BOD concentrations, the goal for the effluent quality of the accelerated treatment system was the same as from conventional oxidation ponds. Recent studies by Weston and Stack (2) had indicated that a turbine aerator could be added to an oxidation pond to increase the rate of oxygen transfer. Their study showed that it was possible to transfer 3 to 4 lb of oxygen/hr/hp.

O'Connor and Eckenfelder (3) discussed the use of aerated lagoons for treating organic wastes. They indicated that a 4-day retention, aerated lagoon would give 60 to 76 per cent BOD reduction. Later, Eckenfelder (4) increased the efficiency of treatment to between 75 and 85 per cent in the summer months. It appeared from the limited information available that the aerated lagoon might offer a satisfactory means of increasing the capacity of existing oxidation ponds as well as providing the same degree of treatment in a smaller volume.

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The paper was presented at the annual meeting of the Central States Sewage and Industrial Wastes Association in Springfield, Ill., June 7–9, 1961.

Red Bridge Subdivision

With the development of the Red Bridge Subdivision south of Kansas City, Missouri, the developer was faced with the problem of providing adequate sewage disposal. The sewerage system from Kansas City was not expected to serve the Red Bridge area for several years. This necessitated the construction of temporary sewage treatment facilities with an expected life from 5 to 15 yr. For the initial development an oxidation pond was constructed as shown in Figure 1. The oxidation pond has a surface area of 4.77 acres and a depth of 4 ft. The pond is currently serving 1,230 persons or 260 persons per acre. In the summer of 1960 the oxidation pond became completely septic and emitted obnoxious odors. It was possible to maintain aerobic conditions in the pond by regular additions of sodium nitrate until the temperature decreased and the algae population changed from blue-green to green algae.

The anaerobic conditions in the existing oxidation pond necessitated examination of other methods for supplying additional oxygen than by sodium nitrate. At the same time further expansion in the Red Bridge Subdivision required the construction of additional sewage treatment facili-

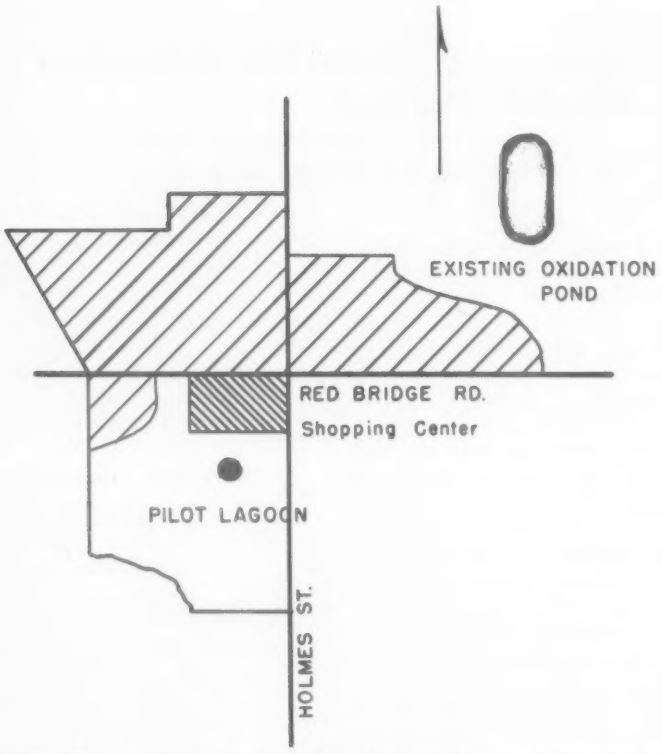

FIGURE 1.—Location map of Red Bridge Subdivision in Kansas City, Mo., showing existing oxidation pond and pilot aerated lagoon.

ties. The large land areas required for oxidation ponds made this type of treatment financially unattractive to the developer. It was proposed that aerated lagoons be used to eliminate the problem at the existing oxidation ponds and to provide the necessary treatment for the additional development.

Pilot Lagoon

The lack of adequate data on the aerated lagoon system prompted the developer to construct an aerated lagoon pilot plant to determine its feasibility for treating domestic sewage. The pilot plant was a circular lagoon 81 ft in diam at the surface and 65 ft in diam at the bottom, 4 ft below the surface, with a volume of 121,000 gal. The side slopes were coated with fiberglas matting coated with asphalt to prevent erosion. The pilot lagoon was located as shown in Figure 1 to serve the area just south of the existing housing area. The major contributor was a shopping center with houses being added to the system as the subdivision developed. The pilot lagoon was designed to handle the wastes from 314 persons with a 4-day aeration period. Initially, the wastewater would be entirely from the shopping center with the domestic sewage from the houses increasing over an 18-month period. This operation would permit evaluation of the pilot plant, with a slowly increasing load, over a reasonable period of time.

The pilot plant was equipped with

a 3-hp turbine aerator (Figure 2). The aerator had a variable-speed drive to permit operation through a range of speeds. The sewage flow into the treatment plant was metered and continuously recorded on 24-hr charts. The raw sewage was introduced directly under the turbine aerator to insure maximum mixing of the raw sewage with the aeration tank contents. The effluent was collected through two pipes and discharged to the Blue River through a surface drainage ditch.

Analyses

Composite samples were collected at weekly intervals. The long retention period and the complete mixing concept prevented rapid changes in either the mixed liquor or in the effluent. Weekly samples would make any changes more readily discernible than daily samples. The composite samples were normally collected over a 6-hr period, but an occasional 24-hr composite was made. Examination of the operations of the shopping center permitted correlation of the 6-hr composite samples with 24-hr operations. The data indicated that the organic load during the 6-hr composites was essentially 50 per cent of the 24-hr organic load.

Grab samples were collected from the existing oxidation pond to determine its operating conditions. Efforts were made to take the grab samples at random periods so that the mass of data could be treated as a 6-hr composite sample. A single 24-hr composite sample indicated that the sewage flow pattern and characteristics were typical.

Pilot Plant Operations

The BOD of the influent to the pilot plant varied between 110 and 710 mg/l with an average of 350 mg/l. This was equivalent to 240 mg/l BOD on a 24-hr basis. The BOD of the raw sewage was typical of domestic sewage from a subdivision. The BOD in the effluent averaged 58 mg/l, a 76-per cent reduction over the 24-hr period. Examination of the data in Table I

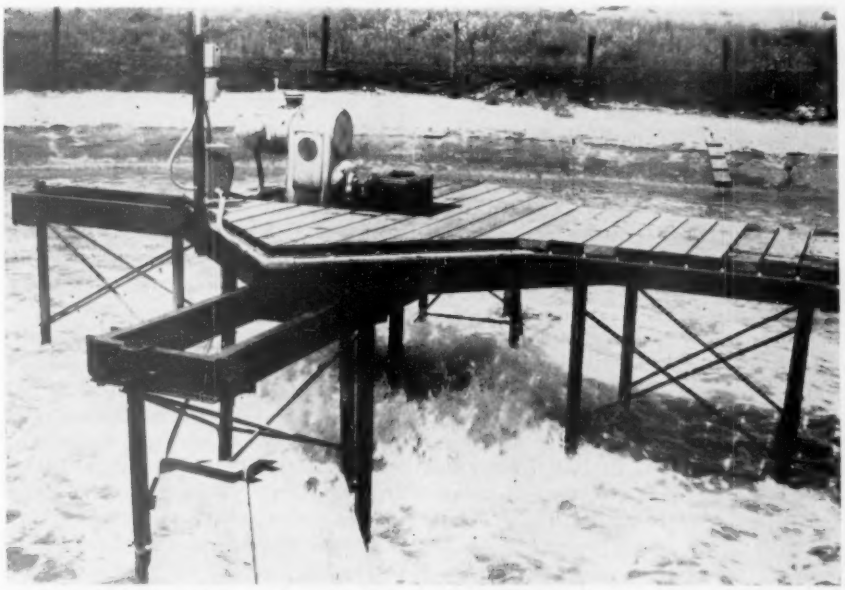

FIGURE 2.—Closeup of mechanical aeration equipment in the aerated lagoon.

TABLE I.—Organic Loading on Aerated Lagoon

Date (1960 and 1961)	BOD (mg/l)			
	Influent	Effluent	Stream	Flow (gpd)
Oct. 5*	510	43	40	—
12*	140	26	8.2	—
19*	125	36	5.5	—
27	125	29	13	14,100
Nov. 8	310	44	7.0	15,100
15†	175	47	8.0	12,800
22	435	52	26	14,200
Dec. 3‡	530	52	12	16,800
20‡	360	42	5.0	13,100
Jan. 3	710	41	21	16,100
12	465	72	24	14,600
29	340	—	4.0	16,000
Feb. 9	540	70	12	14,800
16	250	140	—	11,800
23	195	47	0.0	24,300
Mar. 9	180	87	26	21,700
23§	107	45	13	46,200
30	200	62	12	35,700
Avg	350	58	12	19,000

* 2-hr composites (omitted from averages).
† 7-hr composite.
‡ 5-hr composite.
§ 4-hr composite.
All other composites 6 hr.

shows that a few samples contributed to raising the effluent BOD. The periods of high effluent BOD occurred during cold periods when operational problems with the aerator resulted. Ice caused the aerator to overload, straining the drive belts. The slippage of the drive belts caused the aerator to slow down and reduce oxygen transfer as well as the mixing of the raw sewage.

The organic loading on the unit averaged 32 lb of BOD/day or about 2 lb BOD/day/1,000 cu ft aeration capacity. Needless to say, the organic load was very low on a volumetric basis, but was 270 lb BOD/day/acre on a surface loading basis. It seems that the aerated lagoon was a very heavily loaded oxidation pond or a lightly loaded activated sludge system.

The flow rate remained relatively constant during the winter months as shown in Table I. With the spring rains the flow rose rapidly due to infiltration in open sewers. As construction progresses, the volume of storm drainage will be sharply reduced. The retention period in the aerated lagoon ranged from 9.8 to 2.6 days, averaging 6.4 days.

The large amount of vegetable grindings from the grocery store in the shopping center created a suspended solids problem. The vegetables were not readily metabolized by the bacteria in the aeration unit and tended to float on the surface. A skimming device at the effluent weir prevented loss of most of these light solids. The average volatile suspended solids in the effluent was 75 mg/l while the MLSS averaged 170 mg/l volatile suspended solids. The average sludge age based on displacement of solids was calculated to be 14.5 days. The oxygen uptake rate in the mixed liquor averaged 0.8 mg/l/hr during the first four months of this study. Variations in aerator speeds during the latter two months of this study caused increased mixing and increased oxygen demand. The increase in oxygen uptake rates from 1.2 to 2.6 mg/l/hr which followed an increase in rotor speed was believed to be related to resuspension of solids which had settled at the lower rotor speeds. It appeared that most of the mixed liquor suspended solids were active microbial solids with the heavier, less active solids settling out.

The suspended solids discharged in the effluent were found to be the major source of the BOD. Removal of the suspended solids by a membrane filter yielded an average effluent containing only 20 mg/l BOD. The BOD in the drainage ditch receiving the pilot plant effluent averaged 12 mg/l. This low BOD was due to removal of the excess suspended solids by sedimentation since the only dilution was surface

runoff which was very low during this study.

Microscopic Examination

Routine microscopic examinations were made of the mixed liquor as indicated by McKinney and Gram (5) for the various types of protozoa. It was found that the aerated lagoon was an activated sludge system rather than an oxidation pond. At no time were algae found in the mixed liquor. The bacteria formed typical activated sludge floc. The floc particles were all small as the heavier floc settled out.

Initially, the flagellated protozoa predominated, but they soon gave way to the free swimming ciliated protozoa. As the temperature decreased, the number of free swimming ciliated protozoa decreased. Very little protozoa activity existed below 40°F. When the temperature reached 32°F all protozoan activity ceased; but as the temperature rose, the numbers of protozoa increased rapidly. Only once were stalked ciliates found in the mixed liquor. The predomination of free swimming ciliated protozoa is indicative of a high bacterial population.

TABLE II.—Oxygen Relationships in Aerated Lagoon

Date (1960 and 1961)	DO (mg/l)	O_2 Uptake (mg/l/hr)	Temperature (°F)
Oct. 5	6.3	—	74
12	5.8	0.7	73
19	7.5	0.8	62
27	7.4	0.8	62
Nov. 8	7.7	0.6	51
15	5.4	0.8	62
22	4.0	1.1	54
Dec. 3	6.4	—	41
8	5.8	0.9	45
20	5.8	0.8	38
Jan. 3	5.2	1.0	39
12	5.6	0.9	41
29	0.3	1.0	32
Feb. 9	0.5	—	38
16	—	—	47
23	5.3	1.7	48
Mar. 9	6.8	—	43
23	7.7	1.2	48
30	6.2	2.6	51

TABLE III.—Oxygen Transfer Rate in Aerated Lagoon to Maintain 1.0 mg/l DO

Speed of Rotor (rpm)	Oxygen Transfer Rate (mg/l/hr)	
	Cover On	Cover Off
72	2.5	—
78	—	5.6
82	5.1	—
100	—	8.9
107	7.2	—
117	8.4	9.3

Oxygen Transfer

One of the important aspects of this study was to determine the oxygen transfer relationships of the mechanical aerator. Routine determinations were made for dissolved oxygen in the mixed liquor and for oxygen uptake rates. The data given in Table II show the routine operation of the aerator. The dissolved oxygen in the aeration unit was consistently high until January 29, 1961. An extended cold spell caused ice to build up on the aerator which was mounted on a floating platform and caused the entire platform to sink lower in the water. The added resistance to the rotor damaged the drive belts and reduced the oxygen transfer capacity. It was approximately one month before the belt problem was noticed and corrected, but at no time was there a deficiency of dissolved oxygen.

A series of eight special tests were conducted at different rotor speeds to determine the oxygen transfer rate. Five of the tests were conducted with a polyethylene cover to simulate an ice cover. The rate of oxygen transfer at 1.0-mg/l dissolved oxygen concentration and 10°C for various rotor speeds is given in Table III. The maximum rate of oxygen transfer at 1.0 mg/l dissolved oxygen was calculated as 220 lb/day at a maximum rate of 9.3 mg/l/hr. The actual power requirements indicated 2 lb oxygen transfer/hr/hp. The polyethylene cover reduced the oxygen transfer rate by 10 per cent,

indicating that the maximum oxygen transfer is at the rotor rather than through the surface.

Oxidation Pond

During this study septic conditions developed in the oxidation pond in the spring when the ice melted. Shortly after this study ended septic conditions resulted which required the addition of sodium nitrate. The location of the oxidation pond in a high-value residential area makes odor nuisances a sensitive problem for the developer. The organic concentration in the influent raw sewage ranged from 160 to 270 mg/l of BOD with an average of 230 mg/l. The BOD data are given in Table IV. A single 24-hr composite sample had a BOD of 260 mg/l, indicating a typical domestic sewage. The daily sewage volume to the oxidation pond averaged 147,000 gpd, giving a retention period of 42 days. The organic loading on the pond was slightly under 60 lb BOD/day/acre.

The effluent BOD averaged 34 mg/l, a little lower than that of the study at Fayette (1) indicated for a loading of 60 lb BOD/day/acre. The BOD of the effluent ranged from a minimum of 13 to a maximum of 47 mg/l. Microscopic examination of the effluent showed that minimum BOD occurred when the algae began to decrease with cold weather. When the algae began to build up again, the effluent BOD rose. During the two weeks when the algae disappeared from the effluent BOD's in the effluent were 18 and 16 mg/l. Membrane filter studies showed that removal of the microorganisms from the effluent reduced the average BOD to 11 mg/l.

TABLE IV.—Operational Characteristics of Oxidation Pond

Date (1960 and 1961)	BOD (mg/l)		Dissolved Oxygen (mg/l)	pH	Temperature (°F)
	Infl.	Effl.			
Oct. 5	—	35	16.4	7.7	—
12	—	24	9.2	8.3	—
19	—	30	9.9	8.0	55
27	—	33	9.5	8.9	61
Nov. 8	230	13	15.9	8.7	45
15	210	18	8.2	8.3	—
22	270	16	11.4	8.7	50
Dec. 3	266	18	4.6	7.7	40
8	190	16	3.0	7.7	36
20	200	28	11.2	7.9	37
Jan. 3	240	35	15.2	8.1	33
12	250	39	20.5	8.5	41
29	250	41	8.7	7.9	33
Feb. 9	270	47	7.9	7.7	33
16	220	46	0.4	7.1	45
23	160	42	6.8	7.7	48
Mar. 9	220	35	15.0	8.7	44
30	250	33	7.8	8.1	51

The dissolved oxygen in the oxidation pond was dependent on the activity of the algae. The DO ranged from 20.5 to 0.4 mg/l during the daylight hours. The DO rose rapidly in the morning hours. It was found that a pH of 8 was a good indicator of trouble from an oxygen deficiency. Routine pH measurements can be used to indicate operational characteristics of oxidation ponds.

The predominant algae in this oxidation pond were *Chlorella* and *Euglena*. Generally, small free swimming ciliated protozoa were present in the effluent. Rotifers were observed when nitrates were used as an oxygen source. The blue-green algae predominated when anaerobic conditions developed.

Discussion

The aerated lagoon is nothing more than a homogeneous biological reactor with a long holding time. Its efficiency depends on the rate of growth of the microorganisms and the retention period in the aeration unit. The continuous addition of raw sewage results in the displacement of mixed liquor. In a recent analysis of the complete mixing activated sludge process Doshi (6) presented the fundamental mathematical equations for the homogeneous biological reactor. His equations indicated that 95 per

cent of the raw sewage would be metabolized within 7 hr at 20°C and that the BOD in the effluent was related to the microbial solids displaced from the reactor.

The data obtained in this study confirm the fact that the major source of BOD in the effluent from an aerated lagoon is related to the active microbial solids. The average efficiency of BOD reduction was 76 per cent with normal microbial solids losses and 92 per cent with the microbial solids removed. The key to the effluent quality in the aerated lagoon lies in the removal of the suspended solids. It was noted that the suspended solids settled readily in the drainage ditch to which the effluent was discharged. The settled solids did not create any obnoxious conditions or affect the effluent quality in the drainage ditch. In order to evaluate ponding as a means for removal of the suspended solids, a secondary pond has been built just below the pilot plant to intercept the effluent. The effluent pond will be studied carefully to determine its value and its operational characteristics.

The major advantage of the aerated lagoon is the continuous oxygen transfer caused by the turbine aerator. With normal oxidation ponds the algae produce oxygen only during the daylight hours. The microorganisms require oxygen 24 hr a day so that sufficient oxygen must be stored during the daylight hours to last through the night. In essence the algae are like a mechanical aerator run only 12 to 16 hr a day. The continuous oxygen supply of the mechanical aerator, 24 hr a day, summer and winter, permits the aerated lagoon to handle more wastewater per day per unit volume.

The microbial characteristics of the aerated lagoon are those of an activated sludge system rather than an oxidation pond. The turbidity and turbulence prevent normal algae growths. This means that the entire oxygen demand must be satisfied by the mechanical aerator. It is possible to couple an aerated lagoon and an oxidation pond together to obtain the benefits of both systems. This is the current plan for the existing Red Bridge oxidation pond.

An aerated lagoon with a 24-hr retention period has been proposed ahead of the existing oxidation pond. The microorganisms in the aerated lagoon will metabolize most of the organics in the raw sewage with the production of an appreciable quantity of microbial protoplasms. The excess cells will be discharged in the effluent to the oxidation pond where they will undergo sedimentation and endogenous metabolism. Algae will produce the necessary oxygen for the endogenous metabolism. The aeration section is expected to supply 54 per cent of the total oxygen demand while the oxidation pond is to supply 31 per cent. For every pound of BOD treated, the aerator will supply 0.81 lb of oxygen and the oxidation pond will supply 0.46 lb of oxygen. With a 5-hp aerator the aerated lagoon should be able to handle 600 lb BOD/day without any difficulty. The anticipated BOD load is approximately 300 lb BOD/day or about ½ the capacity of the aeration system. The loading on the oxidation pond will be reduced to 20 lb BOD/day/acre which should not create any special problems. The ultimate BOD load anticipated is 580 lb of BOD/day or about the capacity of the aeration system. At this load the oxidation pond will be treating 38 lb of BOD/day/acre.

The aerated lagoon does not require complex maintenance. The only maintenance that is not required in a conventional oxidation pond is periodic lubrication of the aerator motor. The aerated lagoon has promise as either an intermediate treatment system or as a high-quality treatment system. The percentage BOD reduction for varying retention periods with normal domestic sewage is given in Figure 3

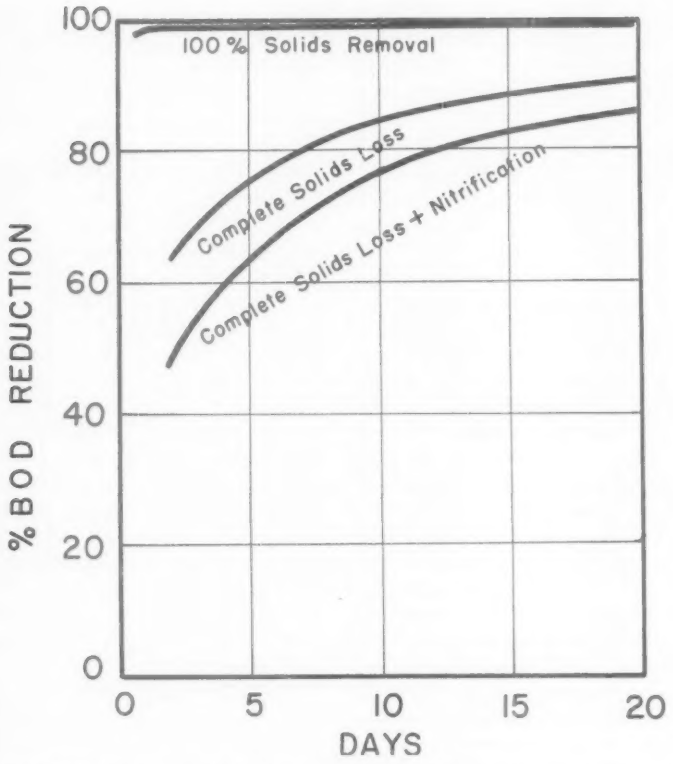

FIGURE 3.—The variation in per cent BOD reduction with aeration time for domestic sewage at 20°C in the aerated lagoon.

for both the intermediate treatment and the high quality treatment.

The aerated lagoon is not the final answer for all waste treatment problems. Like all waste treatment systems it has certain advantages and disadvantages. It appears to have value in areas where oxidation ponds are overloaded or where land is expensive and operational control must be a minimum. The aerated lagoon does not need operational control from a biological standpoint. Biological equilibrium will be established, based on the actual loading conditions and will adjust automatically to various changes in loads. It is sensitive to toxic substances the same as any biological wastewater treatment system. Foam was a problem due to laundromat wastes in the pilot plant, but was easily controlled with daily additions of a commercial antifoam agent.

There are many problems to be solved in the use of aerated lagoons for sewage disposal, but it appears that sufficient data are available to indicate the value of the aerated lagoons. As larger installations are constructed, more data will become available and design criteria will become more sophisticated.

Conclusions

A 6-month full-scale, pilot-plant study of the treatment of raw domestic sewage by an aerated lagoon yielded the following conclusions:

1. The BOD reduction with an average retention period of 6.4 days was 76 per cent.

2. The BOD in the effluent from the aerated lagoon was largely due to the suspended solids. A BOD reduction of 92 per cent was possible with complete solids removal.

3. The mechanical, turbine aerator with variable speed control was capable of transferring 2.0 lb oxygen/hr/hp at 1.0-mg/l dissolved oxygen concentration in the mixed liquor.

4. The aerated lagoon is biologically a long period activated sludge plant and is not related directly to the oxidation pond.

A 6-month examination of the Red Bridge oxidation pond furnished the following conclusions:

1. An organic loading of 60 lb BOD/day/acre emitted obnoxious odors periodically.

2. The average BOD reduction with 42 days' retention was 87 per cent.

3. The BOD in the oxidation pond effluent is largely due to algae.

4. The pH determinations in the effluent were good guides to the oxygen production by the algae. A good algae growth kept the pH above 8, while poor algae growth allowed the pH to drop below 8 and septic conditions to result.

5. A 5-hp aerated lagoon will be constructed ahead of the existing oxidation pond to reduce its organic load, thereby preventing obnoxious odors.

Additional studies are required to determine the following factors:

1. The effect of a secondary-sludge sedimentation pond following the aerated lagoon as an effluent polishing device.

2. The operational characteristics of the aerated lagoon-oxidation pond combination.

3. The mixing characteristics and solids sedimentation within the aerated lagoon.

Acknowledgments

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1. The J. C. Nichols Company for the design and construction of the aerated lagoon pilot plant.

2. Infilco Incorporated for an operational analyses grant.

3. A United States Public Health Service Traineeship Program award.

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EXCESSIVE NITRITE NITROGEN IN ACTIVATED SLUDGE

Charles A. Jaworski and Steven A. Stankey

The Fairfield, Connecticut, municipal sewage treatment plant is a conventional activated sludge plant designed to handle an average flow of 4.0 mgd. The treatment processes include grit removal, comminution, primary sedimentation, aeration, final sedimentation, and chlorination, together with sludge handling facilities consisting of separate sludge digestion tanks, elutriation tanks, and vacuum filters. Plant operational data for a normal period of operation are shown in Tables I and II.

Since the plant effluent is discharged into Long Island Sound in an area that is extensively used for bathing, post-chlorination for effluent disinfection is carried on during the bathing season from May 15 through September 15. Chlorine application is in accordance with the requirements of the Connecticut State Department of Health to meet bacteriological effluent standards set by the Interstate Sanitation Commission (1). Table I shows that during normal operations the chlorine demand of the final effluent averages approximately 6 mg/l and a chlorine residual of at least 1 mg/l is maintained after 20 min contact in a long outfall pipeline. Such a residual has always been found adequate to meet the bacteriological standard which requires that the effluent coliform MPN not exceed 100/100 ml in more than 50 per cent of the samples.

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Chlorine Demand Increase

Each summer for the past several years without any warning or apparent reason the chlorine demand increased excessively, and frequently could not be satisfied even with full use of all chlorinator capacity. The resulting decreases in chlorine residual led to poor bacteriological results. This condition occurred only once during each annual period of chlorination and usually lasted only one to two weeks. Although numerous operational changes were tried during these short periods each year, no definite conclusions could be drawn to indicate a possible remedy for the abnormal conditions.

During the 1960 chlorination season when conditions producing high effluent chlorine demand again occurred, laboratory analyses were performed on several samples collected at various stages of the treatment process. These tests seemed to show that the chlorina-

TABLE I.—Normal Operating Data

Item	Average or Range
Average flow (mgd)	3.0
Aeration period (hr)	6.0
Air to aerators (cu ft/gal)	0.70 to 1.60
Air to aerators (cu ft/lb BOD removed)	1,000
Dissolved oxygen in aerators (mg/l)	2.5 to 4.5
Suspended solids in aerators (mg/l)	1,800 to 2,800
Sludge density index	1.1 to 1.7
Effluent chlorine dosage (mg/l)	6.0
Effluent chlorine residual (mg/l)	1.0 to 2.0

tion difficulty resulted from incomplete nitrification as indicated by the presence of very high nitrites in the unchlorinated final settling tank effluent. The nitrites exerted a high chlorine demand which accounted for the inadequate chlorine residual.

Change in Operation

The ordinary objective in the application of air at the Fairfield plant is to maintain a dissolved oxygen content of about 2.5 mg/l in the aerators with a minimum of 1.0 mg/l at the effluent end of the final settling tanks. When it was found that excessive nitrites were present in the final settling tank effluent it was decided to change the application of air to produce an increase in the dissolved oxygen to at least 4.0 mg/l in the aerators and 2.0 mg/l in the final effluent. This proved successful in effecting a substantial decrease in nitrites present and an increase of nitrates to higher levels, thus restoring the chlorine demand of the plant effluent to normal.

Table III summarizes the findings obtained in connection with this problem and illustrates the relationship between nitrogen constituents and chlorine demand. During the operational difficulty the chlorine demand, which was estimated from operating data and one laboratory test, was appreciably higher than could be expected in settled or even raw sewage. These data, together with the observation that the Fairfield raw sewage at that time exhibited no abnormal chlorine demand during prechlorination, lead to the conclusion that the high chlorine demand was occurring as a result of an upset of the aeration process.

TABLE II.—Laboratory Data During Normal Operation (mg/l)

Determination	Raw Sewage	Primary Effluent	Final Effluent	Per Cent Removal
BOD	157	127	7	96
Suspended solids	190	70	9	95
Organic nitrogen (as N)	15.8	14.3	3.0	—
Ammonia nitrogen (as N)	12.0	13.2	1.5	—
Nitrite nitrogen (as N)	—	—	0.004	—
Nitrate nitrogen (as N)	0.5	0.8	6.0	—

Interference of Nitrites

The chlorine residual results shown in Table III were obtained by using the orthotolidine test. The use of sodium arsenite revealed the presence of substances interfering with the test prior to July 1. While the orthotolidine test is an adequate field control test with an activated sludge effluent, the results reported in Table III for June 27 and 30 are subject to some error due to the nitrite interference. The orthotolidine test should not be used on sewages having more than 2 mg/l nitrite according to "Standard Methods" (2). However, biological and nitrite interferences with the dissolved oxygen tests on the mixed liquor in the aeration tanks were avoided and the accuracy of this test was maintained by the use of the azide-copper

TABLE III.—Relationship Between Nitrogen Constituents and Chlorine Demand (mg/l)

Date 1960	Sample	Nitrate as N	Nitrite as N	Chlorine Demand	Chlorine Residual
June 27	Unchlorinated effluent	2.8	8.0	>40	—
↓	Chlorinated effluent	4.8	1.8	—	Trace
June 30	Chlorinated effluent	4.7	2.5	>25	0.17–0.30
July 14*	Unchlorinated effluent	8.0	0.004	6–8	—
↓	Chlorinated effluent	8.0	0.001	—	1.4–2.0

* The application of air was increased on July 1, 1960.

sulfate-sulfamic acid modifications of the Winkler test.

The following chemical equation may be used to show the reduction of chlorine by nitrite:

$$NO_2^- + H_2O + Cl_2 \rightleftharpoons NO_3^- + 2H^+ + 2Cl^-$$

This equation shows that there is a chlorine demand of 5.1 mg/l for each mg/l of nitrite (expressed as nitrogen). This reaction was observed to proceed very rapidly since the sampling point where low chlorine residuals were obtained is only a few seconds flow time from the point of chlorine application. The rapidity of this reaction has been noted by Gilcreas (3). While some of the Fairfield chlorine demand may have been caused by the presence of insufficiently oxidized suspended or colloidal solids in the effluent, the rapidity of the exertion of the demand, as well as the magnitude of the demand, indicated that a chemical reaction such as that shown above was responsible for most of the chlorine demand.

Nitrogen Tests as Controls

From the standpoint of conservation of water resources, the importance of nitrification in sewage treatment plant effluents is overshadowed by the need for production of an effluent having a low BOD, although in some instances nitrite and nitrate nitrogen may be of appreciable value in supplementing the oxygen supply of a receiving stream. However, nitrification can also lead to undesirable growths of aquatic plants in streams. These considerations for conditions of the receiving waters, as well as the Fairfield experience with respect to chlorination, suggest that routine nitrogen determinations would be of value as control tests, particularly at activated sludge plants where these considerations might be involved. Nitrogen determinations have also been advocated by Sawyer (4) as a guide for controlling nitrification for the purpose of economy in operation of aeration equipment. Routine nitrogen determinations are also essential at plants producing fertilizer for the commercial market.

It is common design practice to assume that activated sludge plant effluents have chlorine demands in the range of 6 to 8 mg/l (5)(6)(7). The chemical reaction cited above and actual plant experience indicated that the Fairfield effluent chlorine demand exceeded 40 mg/l; no activated sludge plant operating at design capacity could have maintained high bacteriological quality of the effluent under these conditions. Where the uses of receiving waters dictate a need for high bacteriological quality, nitrites producing high chlorine demands which exceed chlorinator capacity can be quickly detected by routine nitrogen determinations, the results of which permit intelligent changes in operation before prolonged deficiency in disinfection occurs.

Summary

1. The results of the laboratory examinations on the samples collected, and the chemical equation for reduction of chlorine by nitrite give an adequate explanation for the high chlorine demand in the Fairfield plant effluent. Each milligram per liter of nitrite (expressed as nitrogen) exerted a chlorine demand of 5.1 mg/l, with the reaction proceeding very rapidly. Increasing the amount of applied air significantly decreased the nitrites in the plant effluent and lowered the chlorine demand, with resulting improvement in effluent bacteriological quality.

2. Routine nitrogen determinations at activated sludge plants may be helpful as control tests where any of the following conditions may be encountered:

(*a*) High chlorine demand from nitrites, particularly if continu-

ously excellent bacteriological results are essential,

(*b*) Specific requirement that either high or low nitrification be carried in the effluent from consideration of stream sanitation, or

(*c*) Economy of operation of aeration equipment is desired.

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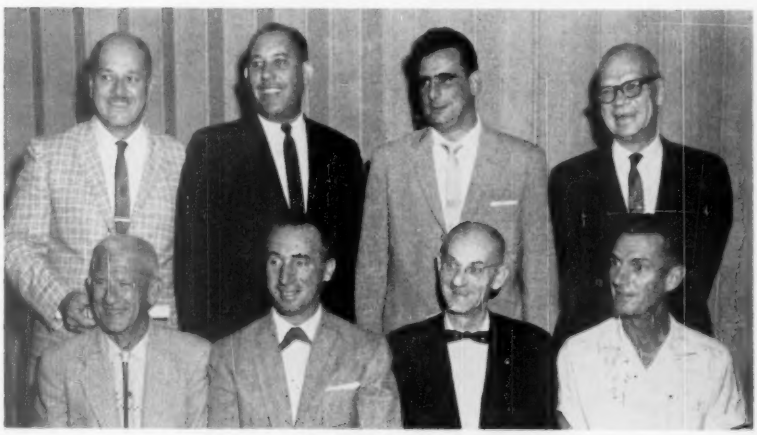
FLORIDA OPERATORS AWARDS



Recipients of the awards for the best operated sewage treatment plants in the State of Florida for 1960–61 are shown above with David B. Lee, Director, Bureau of Sanitary Engineering, Florida State Board of Health, who presented the awards.

Seated are Elmer Potter, Superintendent of Treasure Island plant; Charles Ross, Town and Country Subdivision plant, Tampa; Jack Whitney, Superintendent, Miramar plant; Paul Constable, International Airport No. 2 plant, Miami.

Standing are Eugene Cochran, City of Miami plant; Cliff Courson, Superintendent, Tampa plant; Joe Valdespino, Superintendent, Southwest Orange County plant, Orlando; and Mr. Lee.

WASTEWATER TREATMENT AND DRINKING WATER STANDARDS

M. B. Ettinger

It is topically pertinent to consider raw sewage and sewage in various stages of treatment in relationship to drinking water quality standards since revised standards have been prepared for release. With a few exceptions these follow the pattern described by Hopkins and Gullans (1).

Three groups were involved in developing the new standards:

1. The Advisory Committee on Revision of the Public Health Service 1946 Drinking Water Standard consists of 17 members representing technical societies having competence with respect to water quality requirements and technical control thereof, persons particularly conversant with regional or national water quality problems, or with consumer interests.

2. A technical subcommittee, consisting of Public Health Service officers designated to work with the Committee and to aid the Committee in developing its recommendations.

3. A task force on toxicology composed of well-known toxicologists whose function was to develop and review recommendations on the limitation of toxicants in water to suitable limits.

Bacterial standards in the new drinking water standards are still based solely on the "coliform group," and are similar to those of preceding standards, except that some changes have been made in sampling protocol. The standard says in effect that there should be no more than one "coliform group" organism per 100 ml on the average and that some very careful measures should be taken when the stated limit is exceeded for brief periods.

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The paper was presented at the Central States Sewage and Industrial Wastes Assn. 34th Annual Meeting in Springfield, Ill., June 7–9, 1961.

Coliform Removal

It is well to point out what a sewage treatment plant does to destroy coliform organisms and, more significantly, the enteric pathogens which they serve to indicate.

It all depends on what the plant includes. Primary sedimentation is relatively ineffective—with good luck it may be possible to cut the number of enteric organisms by a factor of two. If there is a trickling filter behind the primary, the bacteria are reduced by a factor of about 5. Activated sludge is still more effective and knocks out about 9 out of 10 enteric organisms (2).

With chlorination, there probably is a further cut by a factor of about 10 unless an exceptional job of chlorination is done. In terms of bacterial destruction the efficiency is likely to compare favorably with what is done in terms of BOD removal. But there is a big difference. If BOD is reduced by 99 per cent there is not much room for further concern on that score, but a 99-per cent removal of coliform organisms leaves an effluent far from being potable water.

The new drinking water standards contain an appendix which discusses

the basis for arriving at the standards. Here it is pointed out that municipal supplies, drawing their raw water from a heavily polluted source, apparently could be responsible for outbreaks of disease caused by enteric viruses, even when the bacteriological results indicate a satisfactory treatment.

Virus Removal

The degree of virus removal in the treatment process is another serious consideration. Here the evidence is very ill-defined because of the difficulties of enumeration of viral material or dosage, but it is clear that a secondary treatment plant is fairly effective. Clarke and Chang (3) and Clarke *et al.* (4) found that primary sedimentation did not yield significant removal of virus material. Activated sludge treatment apparently reduced virus material by a factor of about ten. It was concluded that activated sludge treatment would have to be followed by rigorous disinfection procedures if a virus-free effluent is sought.

Removal of Other Materials

Turning next to the removal of specific chemicals or groups of substances mentioned in the drinking water standards it is noted that performance is highly erratic. At one end of the array, there is little or no reduction of dissolved solids (500 mg/l recommended limit), chlorides (250 mg/l recommended limit), and hopefully, of sulfates (250 mg/l recommended limit). Nitrates probably are increased (45 mg/l recommended limit) at least part of the time if secondary treatment is applied. However, the net effect of the sewage treatment plant is to remove nitrogenous material or dissipate it as nitrogen gas so that there is a decrease in the danger of high nitrates in receiving streams.

The standard recommends that alkyl benzene sulfonate should not exceed one-half mg/l. If the plant is a primary there is very little removal of ABS. Hurwitz *et al.* report that they get out about one-half of the ABS at the Southwest treatment plant in Chicago (5). A conservative estimate based on laboratory data (6) would be about one-third removed by activated sludge treatment.

Phenols (recommended limit) remain at 0.001 mg/l. If phenols reach a primary plant the plant serves to add nutrients and seed and hasten the destruction of the material in receiving waters.

Mathews (7) found that his activated sludge plant was quite effective in reducing phenols to very low levels in the effluents when phenolic wastes from "big steel" at Gary were received.

Cyanide is mentioned in the new standards at two levels: (*a*) recommended limit of 0.01 mg/l and (*b*) a "grounds for rejection" limit of 0.2 mg/l. In a secondary plant the chances are that there will be a good job of destroying most of the cyanide that reaches the plant.

The limit on hexavalent chromium continues to be 0.05 mg/l. Experience with chromates has been related at some length (8). In a secondary plant the chances are good that reduction and removal of much of the chromate that reaches the plant will be accomplished if only a small amount is received. If a heavy dosage is received most of it will go through, although it is believed that with a little redesign an activated sludge plant could be made to reduce or remove all the hexavalent chromium reaching it. This could be done by arranging for the sludge and its food to reduce and precipitate the chromium.

Carbon Chloroform Extract

There is a new operationally defined entity in the drinking water standards. This is carbon chloroform extract (CCE). The parameter is empirically defined as the amount of ma-

terial which can be recovered from a specified activated carbon column which has had a specified amount of water passed through at a prescribed rate and then has been dried and chloroform extracted. The recommended limit is 0.200 mg/l. The technical basis for this limit has been given (9).

Data are meager on what a sewage treatment plant does in the way of removing CCE. However, some estimates can be made. First, a primary plant may be given credit for a reduction which corresponds closely to solids removal. In a secondary plant enough additional material should be taken out to bring the reduction to about 90 per cent, provided oil and grease are not repeatedly circulated through the plant until lost in the effluent.

There are a number of other chemical stipulations in the standards in which the sewage treatment plant intervenes to minimize the amount of toxic or deleterious chemical which reaches a stream. However, most of the more important improvements accomplished in the course of reducing or eliminating solids, BOD, and offensive-looking materials out of effluent have been covered.

Summary

As a group of people connected with sewage treatment plants which empty into inland waters, operators are doing much more than preparing sewage for inoffensive disposal. They are preparing wastes for reuse. The following may be considered to be a motto for the inland operator, "Love thy downstream neighbor and treat your sewage as if you were planning to have it enter your own water supply."

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TIPS AND QUIPS

International Relations

President and Mrs. Kennedy, entertaining the President of Pakistan, were not disturbed by a sign protesting against a proposed wastewater treatment plant across the Potomac. It was removed during the formal dinner held in honor of the visitor.

The photograph, taken by Vic Casamento of the *Washington Post*, shows the small billboard that greets the usual visitor and the far shore of the river. The proposed plant was to have been built in the area near the arrow.

Late reports of the dispute indicate that the planners have retreated and are searching for a new site.

The Potomac River from Mount Vernon.

Engineering Society Moves

The American Society of Mechanical Engineers, founded in 1880, moved its headquarters office on Sept. 2, 1961.

It has been 55 years in the Engineering Societies Building and is now located in the new United Engineering Center at 345 East 47th Street, New York 17.

The new location includes the largest collection of engineering literature in the free world, indexing and abstracting technical literature facilities, meeting and conference rooms, a cafeteria, and exhibit space.

AEC to Reprocess Heavy Water from Foreign Reactors

A. R. Luedecke, General Manager of the U. S. Atomic Energy Commission has authorized its Savannah River Plant to perform heavy water reprocessing services for foreign reactor operators on condition that the heavy water was originally purchased from the Commission. No commercial facilities are available to perform this service.

Heavy water of 99.75 per cent purity is produced in a heavy water extraction facility at the Savannah River Plant

in South Carolina. It is used as a moderator to slow down neutrons in reactors during the fission process. Under agreements with foreign reactor operators, authorized under the Atomic Energy Act of 1954, heavy water which has become degraded during reactor operations will be shipped to the Savannah River Plant for reprocessing and refinement to restore the purity of the material. This service will assist reactor operators to improve reactor efficiency and reduce the amount of heavy water that must be purchased for replacement purposes.

Charges for this service will be set on the Savannah River Plant's cost for upgrading which is based on the percentage of deuterium oxide still remaining in the returned material. Heavy water can become diluted or degraded through absorption of atmospheric moisture and by dilution with light water.

Approximately 500 tons of heavy water produced at the Savannah River Plant have been sold to foreign nations since 1955.

Automatic River Monitoring Station

The first automatic river monitoring station in Pennsylvania operated by the State Health Department was officially placed in operation at Williamsport during public dedication ceremonies July 18. The station is designed to give continuous readings at all times of the condition of the Susquehanna River in the Williamsport area. It is located on the Maynard Street bridge.

Dr. C. L. Wilbar, Jr., State Health Secretary and Sanitary Water Board Chairman, said that the West Branch of the Susquehanna is subject to relatively high concentrations of acidity at times of large runoffs due to heavy rains in upstream areas of mining operations. Such runoffs, he said, have resulted in fish kills in the past. The river has improved so much in recent years that there is now good fishing as far upstream as Lock Haven, Dr. Wilbar reported. This is because of good housekeeping in mining areas in conformity with requirements of the State Health Department.

It is believed that this monitoring station will help pinpoint the source of fish-killing acid mine runoffs, where heavy rains occur in one or another local mining area, and indicate where to concentrate efforts to better control acid mine drainage.

Certified Operators' Pin

The members of the Southwest Texas Regional Short School originated the idea of the lapel pin shown in Figure 2 to encourage water and sewage plant operators to take their certificate of competency examination. The gold-and-blue pin has since become the official emblem of Texas water and sewage treatment plant operators. It is presented to all members who pass the examination for certificates at the short schools.

Texas Certified Operators' lapel emblem.

Harry E. Schlenz, WPCF President, 1961–1962.

MILWAUKEE REPORT

HARRY SCHLENZ PRESIDENT FOR 1962

Harry E. Schlenz, President of the Pacific Flush Tank Company, Chicago, Ill., was elected President of the Federation at the Election Committee meeting on Oct. 8, 1961.

For many years a leader in the field of water pollution control, Mr. Schlenz is well-known to Federation members. He has served the Federation in many capacities, including active participation on the Finance, Public Relations, and Convention Management committees. For two years before his election to the vice-presidency for 1960–61, he served on the Board of Control as a representative of the Water and Sewage Works Manufacturers Association. He was president of the latter organization in 1951 and since that time has been on its Board of Governors.

Born in Denver, Colo., Mr. Schlenz was graduated from the University of Illinois in 1927 with a B.S. in Sanitary Engineering. In 1929 he received an M.S. in Civil Engineering, and in 1933 was awarded the professional degree of Civil Engineer. During 1927–29 when he was taking advanced study at the University of Illinois he was a Research Graduate Assistant with particular emphasis on sludge digestion and sedimentation. This work resulted in the co-authorship of an engineering bulletin on these subjects. He was Instructor in water supply and sewage treatment for the year 1929–30.

His service with Pacific Flush Tank Company began as a Sanitary Engineer in 1930. He was elected to the Board of Directors and Corporate Secretary on January 10, 1934. On March 3, 1936 he was elected Vice-President. Since April 14, 1954 he has been its President.

Mr. Schlenz is a member of Sigma Xi, Tau Beta Pi, Sigma Tau, and Chi Epsilon. In addition to being a longtime member of Central States Sewage and Industrial Wastes Association, he is also a member of the American Water Works Association, American Society of Civil Engineers, Illinois Society of Engineers, American Public Works Association, Engineers' Club of New York, and the Engineers Club of Chicago. He served on the Board of Control of the Athletic Association, University of Illinois, for four years, and as its President in the fourth year.

Mr. Schlenz has served on the Steering Committee of former President Eisenhower's National Conference on Water Pollution and presided at the Plenary Session in Dec. 1960.

He has developed and patented a number of processes and devices in connection with sewage treatment. He is the author of numerous papers in the technical press.

Mr. Schlenz resides in Barrington, Illinois, where he is active in church and civic affairs.

JACK E. McKEE, VICE-PRESIDENT

Dr. Jack E. McKee, Professor of Engineering in Environmental Health, California Institute of Technology, Pasadena, Calif., was elected Vice-President of the Federation at the Election Committee meeting on Oct. 8, 1961.

Before joining the staff of the California Institute of Technology he was partner in the consulting engineering firm of Camp, Dresser and McKee. He was Major in the U. S. Army Corps of Engineers during the Second World War, assigned to the Headquarters, First U. S. Army for the Normandy invasion and campaign in Europe, as sanitary engineer in civil affairs and military government.

Dr. McKee has also done work as Associate Public Health Engineer for the U. S. Public Health Service, New Orleans District, and was a teaching Fellow in the Graduate School of Engineering at Harvard University from 1937 to 1941. From 1936 to 1937 he was an engineering aide with the Tennessee Valley Authority. Among his many other assignments were association with the National Institutes of Health, the Communicable Disease Center of the U. S. Public Health Service, the National Advisory Health Council, and the California Water Pollution Control Board.

Professor McKee is affiliated with the American Society of Civil Engineers, the American Water Works Association, the American Public Health Association, Sigma Xi, Tau Beta Pi, Phi Kappa Phi, Chi Epsilon, and is a Diplomate of the American Academy of Sanitary Engineers.

As a member of the California member association of the Water Pollution Control Federation, Dr. McKee was Director-at-Large for the Federation for 1957–60.

MILWAUKEE MEETING

Once again the Federation's growth was manifested by a record registration at the Milwaukee meeting. The program was crowded with many sessions, both technical and social, and one measure of success was how many activities it was impossible to attend. Total registration was 2,056, including 328 ladies, the number of technical papers presented was 54, and the exhibits numbered 57—all new records. The tabular reporting of attendance shows in detail the breakdown by group and by comparison with other years.

The Local Arrangements Committee, headed by William Konrad, was well prepared for the crowd. The degree of preparation was made evident by the effortless manner in which the events took place.

Bill was very ably supported by his subcommittee chairmen: Fred O. Sullivan, Registration; Raymond D. Leary, Finance; Mrs. William Sivyer, Ladies Entertainment; William Sivyer, Entertainment; Thomas T. Hay, Local Host; Lester C. Schier, Inspection Trip; and B. Victor Pfeiffer, Events.

George Symons and the Program Committee again put together an outstanding technical program. This was the largest program and covered the widest range of subjects ever at a Federation meeting.

Harry Schlenz, as Chairman of the Convention Management Committee, continued his ability to absorb the many details found with meeting arrangements.

The warmth of the people in Milwaukee and the welcome given to the Federation are deeply appreciated and helped make a memorable meeting. The official welcome is seen elsewhere in this report in the form of a lighted sign on City Hall, which was displayed the first day and night of the meeting.

We make Milwaukee City Hall.

President-Elect Schlenz, Senator Moss, and President Lawrence.

All in all the Milwaukee meeting has set a new tenor that will be hard to match in the future. The concept of preregistration is growing as more and more members are taking advantage of this time saver. This year 616 preregistered. Students from nearby universities were invited to attend the technical sessions and view the exhibits at a greatly reduced registration fee, and members that were unable to attend the entire meeting were welcomed to daily attendance also at a reduced rate. These two plans helped immensely in furthering one of the goals of the Federation in the dissemination of knowledge among future and practicing engineers, operators, and researchers.

Technical Sessions

Another "first" this year was the beginning of several of the morning sessions with movies that were entertaining as well as instructive. The movies were carefully selected for their significance and appeal to this group. The 14 sessions were unusually well attended and the speakers brought many new ideas and techniques to the audience.

One governmental and one industrial spokesman highlighted the Federation and Industry luncheons.

Senator Frank E. Moss from Utah spoke from long experience on the problems of pollution viewed from the administrative vantage point. He stated that the federal government's new pollution control bill was the beginning of a crusade in this country against water pollution. John G. Strange, President of the Institute of

Institute of Paper Chemistry President John G. Strange.

Paper Chemistry, covered the particular problems of industrial-pollution abatement at the Industry Day luncheon. He said that industry is assuming an increasing responsibility in the prudent and effective handling of the water it takes in and for reasonable treatment of the water it releases.

Both luncheons, Federation as well as the privately-sponsored Industry Day Luncheon, were well attended and received extensive notice on television, radio, and in the press.

The technical subjects presented ranged from basic research and new ideas to practical design and operation of wastewater treatment plants. The program covered many facets, industrial and municipal, of pollution abatement and those attending were well satisfied in the knowledge gained from each speaker.

Industry Day

Wednesday again was featured as Industry Day. Its success indicated that it will become a regular part of the Federation program. Three times as many industry representatives were in attendance than in 1959, the year before Industry Day was featured. The luncheon attracted 250.

Throughout this day special efforts were made to encourage new people from industry to join the group and share their problems. The technical program is designed for the industry representatives and the Industry Luncheon features an industry authority.

This year Industry Day was cosponsored by the National Council for Stream Improvement, the Institute of Paper Chemistry, the Sulphite Pulp Manufacturers' Research League, and the Northwestern Pulp and Paper Association.

Evening Affairs

The Federation's entertainment on Monday night, "A Night in Old Milwaukee," presented a delightful program of folk dances by the Austrian and Russian Folk Dancers of Milwaukee. Following the folk dancing presentation, music was provided from the bandstand for dancing. True Milwaukee beverages were provided along with various cheeses. This was a wonderful evening that will be long remembered.

The Awards Banquet was equally successful and the evening was a festive affair of 800 members and guests. The presentation of honors to outstanding members was a quiet interlude between dining and dancing.

Inspection Trip

The inspection trip to the Jones Island Treatment Plant was a break in the technical sessions and was very instructive. This plant, one of the few to utilize sludge profitably, is unique in both history and size. The warm, beautiful weather contributed to the large turnout of more than 500.

Public Relations Display

The Public Relations Committee was responsible for one of the finest public relations exhibits at any Federation meeting. It was located in the best possible vantage point, adjacent to the registration area in the Auditorium.

The exhibit consisted of the new Federation display, featuring in full color the aims and activities of the Federation in the fight for water pollution control. The center part of the exhibit was a blow-up of a full-page salute to the Federation from the October 16 *Newsweek*, fronted by an 8-ft sphere-effect and an Associated Press news ticker tape. The left section contained another three-panel display of public relations materials, along with two tables for distribution of literature.

Based on the enthusiasm of the large number taking advantage of the displays, both for on-the-site viewing and later reading of the literature, the entire effort was quite a success.

Exhibits

Water and sewage works manufacturers, 60 companies in 113 booths, contributed greatly to the over-all success of the meeting. There were many new items and concepts presented and each booth was manned by personnel that were well informed about their equipment.

The exhibits were more numerous than in previous years and were extremely well-presented.

Meeting Publicity

News releases on the meeting were mailed in late June and early October to all major Milwaukee and national news outlets, technical and trade publications, as well as other organizations interested in water pollution control. Releases on each paper on the program, with individual write-ups on authors and co-authors, were distributed to each participant's local newspapers, employer, college alumni offices, and suggested trade publications. Releases were similarly distributed for all presiders and co-presiders. Special news releases for recipients of Federation awards were prepared in advance. Pictures taken at the time of presentation were mailed with the releases in the same manner as the releases on the program participants.

On the morning of the first day of the meeting a news briefing session in the newsroom at the Milwaukee Auditorium, featuring coffee and kringles, drew representatives of the Milwaukee newspapers, Associated Press, United Press International, three television stations, two radio stations, the Library, the Museum, *Business Week*, and about 10 trade publications. The Federation's Public Relations Committee members were present to explain the program to the newsmen. News kits with all advance releases and stories, pictures, abstracts, and the program were distributed during the briefing. These kits were prepared so that the newsmen would have complete information in advance of the meeting. There were many news stories on the meeting as a result of these kits. This was the first news briefing at a Federation meeting and it proved extremely successful.

Again this year the voluntary news staff worked in advance of and throughout the week of the meeting to arrange publicity. Those responsible for this great success were Bob Nowak, Pat Doyle, and Mrs. Donna Bergmann, Chain Belt Co.; G. A. Howell and Joe McGinty, U. S. Steel Corp.; Dean Kearsh, J. Walter Thompson Co.; and Bill Ohnemus, the Buchen Co., representing the Cast Iron Pipe Research Assn. Their efforts produced the greatest publicity of any Federation meeting.

Beginning with the half-hour interview of Federation President Ray E. Lawrence on the Sunday evening television program, "Milwaukee Reports," the week of the meeting was filled with daily television interviews of principal speakers, Federation officers, and prominent participants in the meeting. Two television newscasts, four television programs, and a radio interview represent the largest coverage of any Federation meeting by these two news outlets. The Milwaukee Library also made an educational film in color on the proceedings of the meeting.

National publicity of the individual program participants was significantly broader this year. The advance news releases prepared in the Federation office were mailed before the meeting to each participant's home newspapers, employer, alumni offices, and selected trade and technical publications. Impressive results were obtained. Early clippings from the participants already reveal that over 50 per cent of the technical sessions, as well as the election of the Federation officers and the recipients of awards, received publicity in local newspapers throughout the country. There were also special reports and feature articles on the

meeting in nine trade and technical publications.

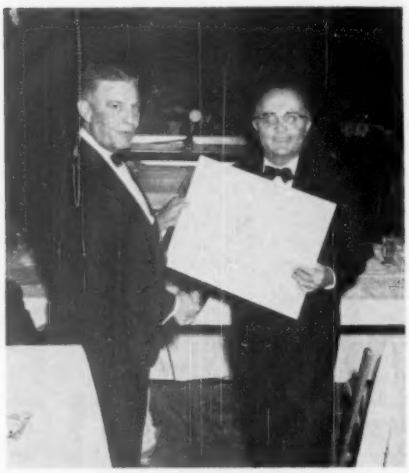
One aspect of Milwaukee hospitality was the interest in the Federation meeting and the wide reporting of the events, personalities, and talks of the meeting. Throughout Monday, Oct. 9, the Milwaukee City Hall illuminated sign read, "Welcome Water Pollution Control Federation." It fully keynoted this hospitable interest of Milwaukee in water pollution control and the tremendously successful publicity of the annual meeting.

Awards for 1961

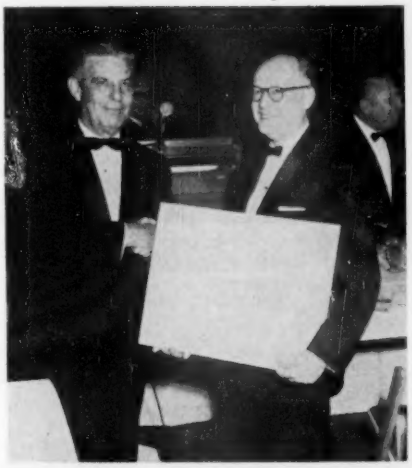
The honors and awards for 1961 conferred by the Board of Control were presented at the Wednesday Awards Banquet by President Lawrence.

Mark D. Hollis was on a business trip outside the U. S. in his capacity as the new Chief Engineer of the World Health Organization, and was unable to accept personally the Past-President's Certificate for exemplary service during 1960.

H. Heukelekian and George Edgar Symons were presented with Honorary Memberships.



H. Heukelekian, right, receives Honorary Member certificate from President Lawrence.



Honorary Member George E. Symons accepts his certificate from President Lawrence.

Dr. Heukelekian, Professor of Sanitary Engineering at Rutgers University, has been an outstanding contributor to the growth of the Federation as Research Committee Chairman, author, and reviewer and abstractor of technical articles.

Dr. Symons, Chairman of the Federation Publications and Program Committee for the past five years, has contributed greatly to the advancement of the Federation. His background, including experience as an operator, consultant, author, and editor has enriched his service to the Federation.

Samuel A. Greeley received the Charles Alvin Emerson Medal for his devotion to the highest principles of the sanitary engineering profession. He was a member of the original committee responsible for the organization of the Federation. Mr. Greeley has long been associated with the firm of Greeley and Hansen, Chicago consulting engineers.

The recipients of the Harrison Prescott Eddy Medal were Henry Nugent Myriek and Arthur W. Busch. This award was given in recognition of

Samuel A. Greeley, right, Emerson Medal winner.

their paper, "The Selective Stimulation of Respiration in Mixed Cultures of Bacteria and Protozoa." This paper, published in the July 1960 Journal, was an outstanding example of fundamental research presented with unusual skill. This work was done at the Rice University, Houston, Tex., where Arthur W. Busch is Research Associate Professor of Sanitary Engineering. Nugent Myrick now is Research Fellow at Washington University, St. Louis, Mo.

Harrison Prescott Eddy Medal winners Arthur W. Busch, center, and Nugent Myrick, right, shown with President Lawrence.

Dietrich Kehr and Wilhelm von der Emde were awarded the George Bradley Gascoigne Medal for their paper, "Experiments on the High Rate Activated Sludge Process," which appeared in the October 1960 Journal. This well-performed work yielded new data and presented a method for the successful treatment of a difficult combination of industrial and domestic wastewaters.

George Bradley Gascoigne Medal winners Dietrich Kehr, center, and Wilhelm von der Emde, right, are congratulated by President Lawrence.

Dr. Kehr is Director of the Institute for Water Supply and Sewage Works at the Institute of Technology, Hanover, Germany; and Dr. Wilhelm von der Emde is Chief Engineer of the Sewage Works Department of the City of Hamburg, Germany.

The Industrial Wastes Medal was given to J. M. Holderby and William A. Moggio for their paper, "Utilization of Spent Sulfite Liquor," as published in the February 1960 Journal. This reported on the problems of dis-

posing of pulp wastes and outlined a method of utilizing these wastes.

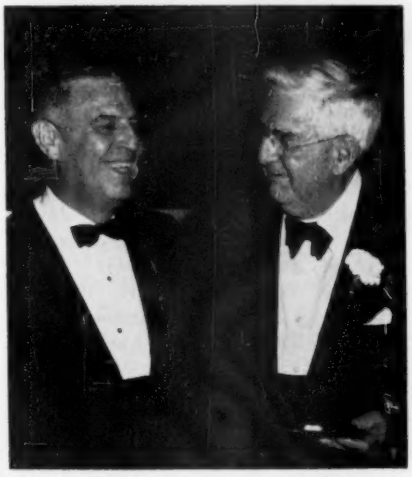
J. M. Holderby, center, and William A. Moggio, right, Industrial Wastes Medal winners, are shown with their plaques after receiving them from President Lawrence.

J. M. Holderby is Manager, Lake States Yeast and Chemical Division of the St. Regis Paper Company, Rhinelander, Wis. W. A. Moggio is Section Head, Felt Products Research, Armstrong Cork Company, Lancaster, Pa.

A highlight of the Awards Banquet was the presentation of the newly created (and well-kept secret) William J. Orchard Award to Bill Orchard. This award is for distinguished service and will be conferred only at such time when a person emerges as an exceptional contributor to the water pollution control field.

William J. Orchard has been closely associated with the Federation's development since its beginning in 1928, having served as Finance Committee Chairman during this entire period.

The newly-created William J. Orchard Award.



Bill Orchard accepting the William J. Orchard Award from President Lawrence.

An added feature of the Awards Banquet was the presentation of the George F. Bernauer Memorial Award to Henry M. Heisig by the Conference of Wisconsin Sewage Works Operators. Mr. Heisig is retired Director of Laboratories for the Milwaukee Sewerage Commission. G. A. Rohlich, Professor of Hydraulic and Sanitary Engineering at the University of Wisconsin, made the presentation.

Nominations for the 1961 Arthur Sidney Bedell Awards, for service to Member Associations of the Federa-

Henry M. Heisig, left, accepting the George F. Bernauer Award from Gerard A. Rohlich.

tion, were confirmed by the Board as follows: T. W. Clapham (Arkansas); Gerson Chanin (California); James W. MacLaren (Canada); E. J. Beatty (Central States); Hayse H. Black (Federal); Thomas de S. Furman (Florida); Paul L. Brunner (Indiana); Philip F. Morgan (Iowa); C. B. Townend (ISP-England); Grant S. Bell (Kentucky-Tennessee); Sinclair S. Crawford (Louisiana); Huntley DeLano (Michigan); Theodore A. Filipi (Nebraska); Morris M. Cohn (New York); Walter M. Franklin (North Carolina); Gilbert H. Dunstan (Pacific Northwest); George A. Elias (Pennsylvania); Russell A. McCoy, Jr. (South Carolina); Ragnar Spaak (Sweden); and A. C. Bryan (Texas).

Nominations for the 1961 William D. Hatfield Awards, for outstanding treatment works operation, were confirmed by the Board as follows: T. W. Clapham (Arkansas); Ray L. Stoyer (California); Leslie W. Sharman (Canada); Carl A. Lund (Central States); F. J. Ludzack (Federal); E. Charles Shreve, Jr. (Florida); William Edwin Ross (Indiana); L. F. Skorczeski (Iowa); Robert W. Huie (Kentucky-Tennessee); E. E. Dupre (Louisiana); Leonard Hillis (Michigan); Elijah Coffman (Nebraska); Kenneth E. Carrington (New York); John S. Welch (North Carolina); Kenneth L. Larson (Pacific Northwest); Chester Ford (Pennsylvania); Ralph G. Pennington (South Carolina); Erik Thore (Sweden); and Haskell R. Street (Texas).

Membership

The Secretary reported that the combined Honorary, Active, and Corporate Membership of the Associations constituting the Federation was 8,692 on Sept. 30, 1961, representing a substantial gain over 1960's 8,559. Twenty-nine associations showed membership gains; 13 registered losses, and 2 showed no change.

The number of Associate Members was 87, an increase of 2 over 1960.

The New York Association won the membership prize for the largest numerical increase by gaining 54 new members. Louisiana won the percentage increase with an impressive 87.5 per cent. West Virginia was second with 22 per cent.

Directors-at-Large

The new Director-at-Large is Arthur D. Caster, Principal Engineer, Sewage Disposal, Division of Water Pollution Control, Cincinnati, Ohio.

The new Federation Director representing the Water and Sewage Works Manufacturers Association is W. A. Hardenbergh, Editor and President of *Public Works*, Ridgewood, N. J.

Bedell and Hatfield Award Nominations

The accompanying schedule of Bedell and Hatfield Award nominations was approved by the Federation Board of Control on Oct. 8, 1961. The award schedule is included for the current three-year period. Those Member Associations with changes in membership which place them in a different cate-

Bedell and Haffield Award Schedule

(Date of Award is year submitted to Board of Control)

Member Association	Members		Nominations Per 3 years	Future Schedule		
	9-30-60	9-30-61		1962	1963	1964
Alabama	46	43	1	—	√	—
Alaska	15	13	1	—	√	—
Arizona	50	55	1	—	√	—
Arkansas	36	35	1	—	—	√
California	605	611	3	√	√	√
Canada	644	635	3	√	√	√
Central States	617	618	3	√	√	√
Federal	92	83	1	—	—	√
Florida	430	398	2	—	√	√
Georgia	82	99	1	√	—	—
Germany	48	54	1	—	√	—
Indiana	281	332	2	—	√	√
Iowa	136	137	1	—	—	√
IPHE (England)	21	22	1	—	√	—
ISP (England)	113	105	1	—	—	√
Israel	0	7	1	—	√*	—
Kansas	135	134	1	—	√	—
Kentucky-Tennessee	191	204	1	—	—	√
Louisiana	16	30	1	—	—	√*
Maryland-Delaware	87	87	1	√	—	—
Michigan	503	506	3	√	√	√
Mississippi	89	84	1	—	√	—
Missouri	72	85	1	—	√	—
Montana	38	45	1	√	—	—
Nebraska	66	74	1	—	—	√
New England	413	457	2	√	√	—
New Jersey	330	346	2	√	√	—
New York	661	715	3	√	√	√
New Zealand	40	40	1	—	√*	—
North Carolina	168	181	1	—	—	√
North Dakota	19	16	1	√*	—	—
Ohio	441	451	2	√	√	—
Oklahoma	48	47	1	√	—	—
Pacific Northwest	355	359	2	—	√	√
Pennsylvania	505	526	3	√	√	√
Puerto Rico	78	90	1	√	—	—
Rocky Mountain	131	134	1	√	—	—
South Carolina	58	68	1	—	—	√
South Dakota	43	51	1	√	—	—
Sweden	125	125	1	—	—	√
Switzerland	17	17	1	—	√*	—
Texas	238	244	1	—	—	√
Utah	52	51	1	—	√	—
Virginia	164	167	1	√	—	—
West Virginia	91	111	1	√	—	—
Totals	8,376	8,692	63	19	23	19

* Year eligible to petition for nominations.

gory for award eligibility are included in the future schedule.

Kansas City in 1966

The Meeting Place Committee recommended, and the Board approved, Kansas City, Mo., as the 1966 meeting place. The convention will be held Sept. 25–29, 1966, using the facilities of the Municipal Auditorium and the Hotel Muehlebach. Previously approved and announced dates and locations are:

1962, Toronto, Canada, Royal York Hotel, Oct. 7–11.

1963, Seattle, Wash., Olympic Hotel, Oct. 6–10.

1964, Bal Harbour, Fla., Americana Hotel, Sept. 27–Oct. 1.

1965, Atlantic City, N. J., Traymore Hotel, Oct. 10–14.

1961 MEETING STATISTICS

Comparative Registration Totals with Past Years

Year	Location	Men	Ladies	Total
1961	Milwaukee	1,728*†	328	2,056
1960	Philadelphia	1,395	325	1,720
1959	Dallas	1,035	237	1,272
1958	Detroit	1,111	238	1,349

* Includes women operators, etc.
† Includes 262 one-day registrants.

REGISTRANT CATEGORIES

Category	Year			
	1961	1960	1959	1958
Consulting Engineers	230	240	170	164
Municipal Officials	26	10	11	17
Municipal Mgr., Supt., Engr., Chem.	305	290	231	273
Regulatory Personnel (Fed., State)	142	138	105	94
Teaching Personnel and Students	100	51	79	68
Industrial Supt., Engr., Chem.	167	138	68	72
Manufacturer's Representatives	720	505	349	425
Miscellaneous*	38	23	22	8
Ladies	328	325	237	238
Totals	2,056	1,720	1,272	1,349

* Representatives of WPCF, WSWMA, AWWA, retired persons, foreign registrants (outside U. S. and Canada), and persons who did not identify business.

REPORT ON BOARD MEETINGS

The Board of Control meetings demonstrated that the Federation truly is an international organization. Representatives were on hand from member associations from Canada, England, Germany, Israel, New Zealand, Sweden, and Switzerland.

At this meeting significant changes in constitutional committee leadership were witnessed.

As Chairman of the Finance Committee since the Federation's beginning in 1928, William J. Orchard has rendered outstanding guidance in the period of formative and maturing growth of the Federation when his expert experience was most valuable. The Finance Committee is now privileged to be headed by Robert F. Orth who is extremely well-fitted for the job of guiding the fiscal policies of the Federation.

George E. Symons brought to a close his five years as Chairman of the Publications and Program Committee. It is difficult to realize the amount of time and effort necessary to perform the enormous task of putting together the annual meeting program. The responsibility for the expanding publications also has been a challenging task. George Symons has performed in a flawless manner in these duties. Paul Haney as incoming Chairman faces the same problems in addition to the new responsibilities of the increasing needs of a growing organization.

Special appreciation was extended to John W. Wakefield who ended his service as Chairman of the Organization Committee. B. A. Poole is the incoming Chairman.

Morris M. Cohn as Chairman of the Sewage and Industrial Wastes Practice Committee for the past 19 years has performed outstandingly in guiding the extensive and comprehensive manual of practice publication program. Under his leadership 11 manuals of practice have been published and several others are underway. As incoming Chairman, Don E. Bloodgood will assume the important task of continuing and expanding the manual of practice program as well as other professional or technical standards for the Federation.

H. Heukelekian completed his illustrious service as Chairman of the Research Committee, a post he has held for the past eight years. During this time one of his most noteworthy accomplishments has been the annual Review of Literature published in the Journal. D. A. Okun accepted the Chairmanship of this important committee.

In a summary of the trend in member association name changes it was noted that 22 U. S. associations have changed their names to one including "Water Pollution Control" or a similar name. These 22 associations represent 75 per cent of the U. S. membership.

An active public relations program was directed by Committee Chairman G. A. Howell and outlined in his report. News coverage was an overwhelming success at the Milwaukee meeting. Two display booths demonstrating the activities of the Federation and public relations materials were developed and used at several meetings throughout the year.

The Board authorized the establishment of a Membership Promotion Committee which will become active during the year.

At the request of Finance Committee Chairman Robert Orth, Bill Orchard presented the Committee's proposed budget totaling $194,825, including $5,000 for transfer to surplus and $15,418 for public relations and

operator advancement. The unaudited net worth as of Sept. 30, 1961, was $126,417.

Resolutions of appreciation were expressed to the many who helped make the Milwaukee meeting a tremendous success. Special appreciation was extended to the host Central States Sewage and Industrial Wastes Association; to the Local Arrangements Committee, William N. Konrad, Chairman; the Ladies Entertainment Committee, Mrs. William Sivyer, Chairman; and the Milwaukee Sewerage Commission, Ray D. Leary, Chief Engineer and General Manager.

A resolution was passed expressing sincere wishes for a speedy recovery to Don E. Bloodgood who suddenly became ill during the meeting.

NEW YEAR PREPARATIONS

An Editorial

The end of a year is a natural time to examine the year's production and accomplishments. Our blessings are many and, in spite of trials and tribulations, we can all find much for which we can be justly thankful.

As an organization, your Federation may also be thankful for steady progress and it can take pride in its achievements. More importantly it can look to the future and find it both challenging and bright. It must always be alert to the opportunities of service to the water pollution control field.

We must remember that the Federation is a service organization and that the better its service, the better for all associated with it. Federation publications are for the benefit of the entire water pollution control field, of which the membership is the solid core. A regular and valuable membership service is the complete biennial membership directory. The next printing will be as Part 2 of the March 1962 Journal.

It is the responsibility of the Journal staff to print this Directory as accurately as possible. This is a most painstaking task because of the seemingly infinite detail of the members' titles, addresses, and member association affiliation. To assist with this information, we urgently request you to inform the Federation office of any change in your job title, employer, or address at any time this occurs. Please always supply your current address, as this is the key to your card location in the file. For the 1962 Directory, however, it is urgent that this information be correct and in the office of the Federation as promptly as possible. If you were listed with any inaccuracies in the Directory of March 1960 and/or the Supplementary Directory in March 1961 and you have not taken the trouble to correct this information on file since that time, you are urged to send this in as promptly as possible. Such information should be available in the Federation office early in January, though we realize this may appear to be an unreasonably early date. Our primary appeal is for you to send such changes promptly and you are assured we will do all possible to handle the information correctly.

Finally, we wish to urge all Federation members to send 1962 dues to their member association secretary in ample time for him to forward the Federation portion of the dues to reach here by January 31. This will assure the crediting of your 1962 dues without the danger of interrupting your subscription and will save the cost and labor of cutoff and later restoration. Prompt payment not only increases efficiency and economy but reduces the danger of processing errors.

The Federation wishes to give you complete service. Your cooperation in these details will be greatly appreciated.

R. E. F.

NEWS AND NOTES

People and Events in the Wastewater Field

Among the top ten public works men in 1960 as chosen by the American Public Works Association were four prominent Federation members: **David V. Auld**, Director of Sanitary Engineering, Government of the District of Columbia; **Hugh A. Benner**, Director of Public Works, Saginaw, Mich.; **Robert H. Hess**, Director of Water and Sewage, Wichita, Kans.; and **David B. Lee**, Director, Bureau of Sanitary Engineering, Florida State Board of Health.

Frank L. Heaney has joined the staff of **Camp, Dresser & McKee**, Boston, Mass. He formerly was a senior engineer with **Fay, Spofford & Thorndike, Inc.**, of Boston.

Jesse H. Barlow, Superintendent of the Treatment Plant Division of the Metropolitan St. Louis Sewer District became the first recipient of the Annual Citation of the Missouri Water Pollution Control Association.

William C. Gibson, Associate Professor of Public Health Engineering at the University of Michigan School of Public Health, died recently.

David S. Caverly and **George M. Galimbert** have been named Assistant General Managers of the Ontario Water Resources Commission. They also will continue their former responsibilities, Mr. Caverly as Director of the Plant Operations Division and Mr. Galimbert as Director of the Sanitary Engineering Division. In the same organization **K. H. Sharpe** has been named Assistant Director of the Sanitary Engineering Division and **K. E. Symons** has been appointed as Assistant Director of the Water Resources Division.

Roy B. Everson, founder of **Everson Manufacturing Co.**, died recently. He was one of the pioneers in the development of chlorination equipment.

Cincinnati recently dedicated its new Muddy Creek Sewage Works.

John T. O'Connor has been appointed as Assistant Professor of Sanitary Engineering in the Department of Civil Engineering at the University of Illinois.

Gerald H. Teletzke has joined the **Zimpro Division of Sterling Drug, Inc.** He has been Director of Sanitary Engineering Research for **Eimco Corporation.**

Oswald H. Scott, General Manager and Secretary of the Belleville Utilities Commission, Belleville, Ont., has retired after 48 years of service with the Commission and its predecessors.

Rolf Eliassen, Professor of Civil Engineering at Stanford University, has been admitted to partnership in the firm of **Metcalf & Eddy**, Boston, Mass. He will be Resident Partner in the firm's new office in Palo Alto, Calif.

Blucher A. Poole, State Sanitary Engineer of the Indiana State Board of Health, has been elected Chairman of the Steering Committee of the State and Interstate Water Pollution Control Administration, succeeding **Milton P. Adams**, Executive Secretary of the Michigan Water Resources Commission. Mr. Poole also is Chairman of the Federation Organization Committee.

C. Fred Gurnham has resigned from Michigan State University as Professor and Head of the Department of Chemical Engineering. He will practice as a consulting chemical and sanitary engineer, specializing in the field of industrial wastes.

Bruce M. McDill, Chief of the Sewage and Industrial Wastes Unit of the Division of Sanitary Engineering of the Ohio Department of Health, recently retired after 36 years with the Department. Since the Water Pollution Control Board was begun in 1951, he has been its principal advisor on industrial waste problems.

Infilco Inc. has consolidated all its municipal water and sewage treatment operations in the U.S. and Canada into a newly formed Public Works Department. **G. E. Hauer** will manage the new department.

David W. Carmichael recently ended 20 years as borough engineer of Verona, N. J. to return to private consulting practice and to resume graduate study.

VAREC GAS BURNER

"A CURTAIN OF FLAME" INSURES POSITIVE IGNITION OF WASTE GAS

Varec engineers designed a double orifice in the pilot flame ring (A). The ring encircles the waste gas nozzle (B)... forms an actual "curtain of flame" that all waste gas must pass through... and which positively ignites the gas.

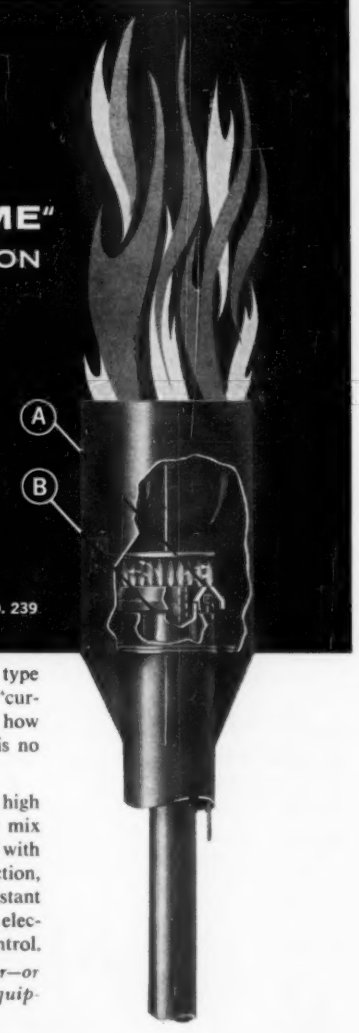


FIG. NO. 239

Varec eliminates ignition problems with its new flare type Fig. No. 239 Waste Gas Burner. The burner's unique "curtain of flame" provides dependable ignition no matter how variable the flow of gas through the burner. There is no loss of pilot flame due to down draft.

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- **SEWER DESIGN AND CONSTRUCTION**

COMPANION VOLUMES IN THE FEDERATION MANUAL SERIES

(Produced Jointly with ASCE)

"Sewage Treatment Plant Design," 374 pages of the latest information for those interested in plant design. (WPCF MOP 8).

"Design and Construction of Sanitary and Storm Sewers," the widely used sewer manual containing 283 pages of comprehensive information, including more than 100 illustrations. (WPCF MOP 9).

Each manual is offered to members at $3.50, and to others at $7.00.

Bring your reference library up to date with the addition of these authoritative volumes.

See Publications Page in this issue for other details and convenient order coupon.

WATER POLLUTION CONTROL FEDERATION

4435 Wisconsin Avenue Washington 16, D. C.

EQUIPMENT AND SUPPLIES

New Catalog—Describes available sluice gates and auxiliary equipment as well as giving a great deal of technical flow data. 212 pages. Rodney Hunt Machine Co., Orange, Mass.

Level Control—A fail-safe material level control, reported to be simple, positive and fail safe, is now being marketed. It consists of a stainless steel probe that is sensitive to the material surrounding it. Changes alter the electrical capacitance that operates the control relays. Explosion proof, it is useful in liquid or solid materials. Flo-Tronics, Inc., 712 West Ontario Ave., Minneapolis 3, Minn.

Split-Case Centrifugal Pumps—New eight-page bulletin illustrates and describes the complete line of Horizontal Split-Case Pumps manufactured by the Aurora Pump Division, New York Air Brake Company, Aurora, Ill.

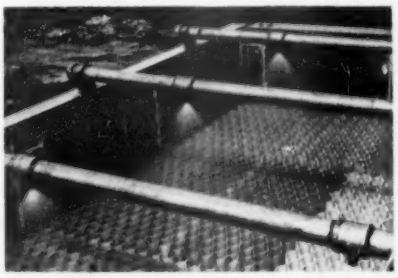
Flow Distribution Nozzle—A distribution nozzle that adjusts automatically to the sewage flow to spread the flow equally over the filter bed is announced by the American Well Works, Aurora, Ill.

Variable-Speed Control—A new balance-beam control for variable-speed drives. This device, utilizing an upset balance principle, adjusts the pumping capacity. The Serv-trol bulletin is available from Healy-Ruff Company, 2285 University Ave., St. Paul 14, Minn.

Elapsed-Time Meter—A new elapsed-time meter for timing of servicing and maintenance of equipment is available in several sizes and designs for panel or separate mounting. General Electric, Schenectady 5, N. Y.

Portable pH Meter—A new meter features a ± 500 millivolt scale and a shock-resistant full-range electrode. Model Electrion II reportedly gives accurate and constant readings. Sel-Rex Instruments Division, The Meaker Company, Nutley, N. J.

Plastic Filter Media—A new plastic packing for efficient treatment of waterborne wastes in trickling filters is now being produced by Dow. Special configuration of the Saran sheets, corrugated in two directions, is designed to distribute the liquid over large surface areas and still provide a high percentage of void space for natural draft ventilation. Complete information, including documentation of pilot-plant studies, may be otained from Dow Industrial Service, Division of the Dow Chemical Company, 20575 Center Ridge Rd., Cleveland 16, Ohio.



Combination Refrigerator and Freezer—A new cabinet-sized refrigerator, 34½ in. high by 23 in. wide by 20 in. front to back, providing 4 cu ft of space, is being produced by Fisher Scientific. A standard bench-top can be installed without contact to the unit to minimize vibration and disalignment. Fisher Scientific Co., 419 Fisher Building, Pittsburgh 19, Pa., or in Canada 8505 Devonshire Rd., Montreal 9, Quebec.

WATER POLLUTION CONTROL PRODUCT GUIDE

This list of products and services is offered as an information aid. The list was derived by solicitation from those firms listed. The JOURNAL will make every effort to keep this list current with the help of Associate Members and advertisers. All Associate Members and all advertisers for the past year are included. Many of the services and products are advertised in this issue. For an alphabetical listing see Index to Advertisers in back of JOURNAL. Write to the Federation office for complete address and representative.

Aerators (*also see* Diffusers, Air)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Infilco Inc.
Link-Belt Co.
Pacific Flush Tank Co.
Permutit Co., Div. of Pfaudler Permutit Inc.
Smith & Loveless
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.
Yeomans Brothers Co.

Agitators
Link-Belt Co.

Air Cleaning Equipment
Westinghouse Electric Corp.

Air Compressors (*also see* Blowers, Compressors, and Fans)
Chicago Pump Co.
Fairbanks, Morse & Co.
Ingersoll-Rand Co.
Komline-Sanderson Engr. Corp.
Worthington Corp.
Yeomans Brothers Co.

Air Diffusers (*see* Diffusers, Air)

Asbestos Cement Pipe Products
Filtration Equipment Corp.
Industrial Materials Co.
Johns-Manville Sales Corp.
Keasbey & Mattison Co.

Ash Handling Equipment
Link-Belt Co.

Bearings
Link-Belt Co.

Bins, Storage (*see* Tanks)

Biologists (*see* Professional Services, elsewhere in this issue)

Blowers (*also see* Air Compressors, Compressors, and Fans)
Chicago Pump Co.
Ingersoll-Rand Co.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Sutorbilt Corp.
Walker Process Equipment Inc.
Yeomans Brothers Co.

Boilers
Combustion Engineering, Inc.

Building Maintenance Equipment and Supplies
Homestead Valve Mfg. Co.

Cast Iron Pipe Products
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
Industrial Materials Co.
U. S. Pipe & Foundry Co.
R. D. Wood Co.

Cement (*see* Concrete)

Centrifuging Equipment
Bird Machine Co.
Permutit Co., Div. of Pfaudler Permutit Inc.

Chains
Chain Belt Co.
Link-Belt Co.

Chemical Feed Equipment
Builders-Providence Div., B-I-F Industries
Capital Controls Co., Inc.
Eimco Corp.
Fischer & Porter Co.
Graver Water Conditioning Co.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Omega Div., B-I-F Industries
Permutit Co., Div. of Pfaudler Permutit Inc.
Proportioneers Div., B-I-F Industries
Wallace & Tiernan Inc.

Chemicals
Brooks Chemicals, Inc.
Dow Industrial Service
Fisher Scientific Co.
General Chemical Div., Allied Chemical Corp.
Hach Co.
Tennessee Corp.

Chemists (*see* Professional Services, elsewhere in this issue)

Chlorination Equipment
Builders-Providence Div., B-I-F Industries
Capital Controls Co., Inc.
Fischer & Porter Co.
Graver Water Conditioning Co.
Wallace & Tiernan Inc.
Zimmer & Francescon

Clarifier Equipment (*also see* Sedimentation Equipment)
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Graver Water Conditioning Co.
Hardinge Co., Inc.
Infilco Inc.
Jeffrey Mfg. Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Link-Belt Co.
Permutit Co., Div. of Pfaudler Permutit Co.
Walker Process Equipment Inc.
Yeomans Brothers Co.

Clay Pipe Products
W. S. Dickey Clay Mfg. Co.
Industrial Materials Co.
National Clay Pipe Mfrs., Inc.
Robinson Clay Product Co.

Coatings and Linings (Pipe and Tank)
Amercoat Corp.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Lock Joint Pipe Co.
National Water Main Cleaning Co.
Stebbins Engr. & Mfg. Co.

Comminutors (*also see* Shredders and Grinders)
Alpha Ltd. (Switzerland)
American Well Works
Chicago Pump Co.
Dorr-Oliver Inc.
Gruendler Crusher & Pulverizer Co.
Infilco Inc.
Jeffrey Mfg. Co.
Smith & Loveless
Walker Process Equipment Inc.
Worthington Corp.

Compressors
Chicago Pump Co.
Fairbanks, Morse & Co.
Ingersoll-Rand Co.
Komline-Sanderson Engr. Corp.
Roots-Connersville Blower, Div. of Dresser Industries Inc.
Worthington Corp.
Yeomans Brothers Co.

Computers
Minneapolis-Honeywell Regulator Co., Brown Instruments Div.

Concentrators (*see* Sludge Concentrators)

Concrete
Portland Cement Assn.

Concrete Pipe Products
American Concrete Pressure Pipe Assn.
Industrial Materials Co.
Lock Joint Pipe Co.
Price Brothers Co.

Construction Equipment
Chain Belt Co.
Eimco Corp.
Ingersoll-Rand Co.
Worthington Corp.

WPCF publications

Safety in Wastewater Works

Information on hazards, accident statistics, rescue methods, safe practices, and equipment. *56 pages. $0.75 to members; $1.50 to others. Item MOP-1.**

Utilization of Sewage Sludge as Fertilizer

An authoritative evaluation of advantages and limitations of sludge as a soil conditioner. *120 pages. $0.75 to members; $1.25 to others. Item MOP-2.**

Air Diffusion in Sewage Works

History and modern practice in design, installation, operation, and maintenance of diffuser systems and appurtenances. *75 pages. $1.00 to members; $1.25 to others. Item MOP-5.**

Units of Expression for Wastes and Waste Treatment

Lists of recommended units for quantities ordinarily encountered in wastes and waste treatment. *8 pages. $0.25 to members; $0.50 to others. Item MOP-6.**

Sewer Maintenance

A guide for maintaining a municipal or industrial drainage system in serviceable condition. *64 pages. $1.00 to members; $1.50 to others. Item MOP-7.**

Sewage Treatment Plant Design

Prepared jointly with ASCE. Detailed presentation of the subject. *375 pages. $3.50 to members; $7.00 to others. Item MOP-8.**

Design and Construction of Sanitary and Storm Sewers

Prepared jointly with ASCE. Detailed presentation of the subject. Issued early in 1960, now reprinted with extensive corrections to several pages. (Complimentary reprint of the corrected pages available for 1960 edition.) *283 pages. $3.50 to members; $7.00 to others. Item MOP-9.**

Uniform System of Accounts for Wastewater Utilities

A completely revised, 72-page manual of the 1949 accounting manual. Provides the entire accounting procedure for a utility. *$2.00 for members; $3.00 for others. MOP-10.**

Operation of Wastewater Treatment Plants

Recently serialized in *Journal*, now bound as a manual. Tremendously helpful for plant operators, with nearly 200 pages, fully illustrated. *$2.00 for members; $3.00 for others. MOP-11.**

Twenty-Year Index to *Sewage Works Journal*

Covers *Sewage Works Journal*, 1928-1948. Author, subject, and geographic. *144 pages. Buckram bound, $3.00. Item Dex-20.*

Ten-Year Index to *Sewage and Industrial Wastes*

Covers *Sewage and Industrial Wastes*, 1949-1958. Author, subject, and geographic. *168 pages. Buckram, $4.00; heavy paper, $3.00. Item Dex-10.*

Glossary—Water and Sewage Control Engineering

Prepared jointly by the Federation, ASCE, AWWA, and APHA. 2,600 terms pertaining to nomenclature. *274 pages. $1.00. Item Gl.*

Binder

Multiple wire, 2-in. capacity, for all MOP's listed except 8 and 9. *$2.00. Item Bi.**

* Discount of 15% on orders for 12 or more of any one manual.

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MOP-6			MOP-11			Bi.		
MOP-7								

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Conveyors
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Stuart Corp.

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Amercoat Corp.
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Inertol Co., Inc.
Johns-Manville Sales Corp.
Koppers Co., Inc.
Lock Joint Pipe Co.
A. O. Smith Corp.
Wallace & Tiernan Inc.

Couplings
Link-Belt Co.

Diffusers, Air (*also see* Aerators)
Alpha Ltd. (Switzerland)
American Well Works
Carborundum Co.
Chicago Pump Co.
Dorr-Oliver Inc.
Eimco Corp.
Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
Walker Process Equipment Inc.
Wemco Div., Western Machinery Co.

Diffusers, Gas (*also see* Aerators)
American Well Works
Carborundum Co.
Chicago Pump Co.
Eimco Corp.
Infilco Inc.
Walker Process Equipment Inc.
Yeomans Brothers Co.

Digestion Tank Equipment
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
Chicago Pump Co.
Dorr-Oliver Inc.
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Infilco Inc.
Lakeside Engineering Corp.
Link-Belt Co.
Pacific Flush Tank Co.
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Walker Process Equipment Inc.
Yeomans Brothers Co.

Dryers
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Combustion Engineering, Inc.
Eimco Corp.
Hardinge Co., Inc.
Komline-Sanderson Engr. Corp.
Link-Belt Co.
Nichols Engr. & Research Corp.
Stuart Corp.

Ejectors
Komline-Sanderson Engr. Corp.
Smith & Loveless
Tex-Vit Mfg. Co.
Yeomans Brothers Co.

Engineers (*see* Professional Services, elsewhere in this issue)

Engines (Sludge Gas and Petroleum Fuels)
Fairbanks, Morse & Co.
Waukesha Motor Co.
Worthington Corp.

Fans (*also see* Air Compressors, Blowers, and Compressors)
Chicago Pump Co.
Lakeside Engineering Corp.
Westinghouse Electric Corp.

Filter Equipment, Trickling
Alpha Ltd. (Switzerland)
American Well Works
Ralph B. Carter Co.
W. S. Dickey Clay Mfg. Co.
Dorr-Oliver Inc.
Dow Industrial Service
Eimco Corp.
Filtration Equipment Corp.
Industrial Materials Co.
Infilco Inc.
Keasbey & Mattison Co.
Komline-Sanderson Engr. Corp.
Lakeside Engineering Corp.
Nichols Engr. & Research Corp.
Pacific Flush Tank Co.
Smith & Loveless
Trickling Filter Floor Inst.
Walker Process Equipment Inc.
Yeomans Brothers Co.

Filter Materials
Carborundum Co.
Filtration Equipment Corp.
Graver Water Conditioning Co.
Industrial Materials Co.
Johns-Manville Sales Corp.

Filters, Diatomaceous Earth
Graver Water Conditioning Co.
Yeomans Brothers Co.

Filters, Vacuum (*also see* Vacuum Filters)
Bird Machine Co.
Dorr-Oliver Inc.
Eimco Corp.
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Chain Belt Co.
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Dorr-Oliver Inc.
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Jeffrey Mfg. Co.
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PROCEEDINGS OF MEMBER ASSOCIATIONS

CALIFORNIA WATER POLLUTION CONTROL ASSOCIATION

The 33rd Annual Conference of the California Water Pollution Control Association was held in Santa Monica, Calif., Apr. 26–29, 1961. The California Sewage and Industrial Wastes Association voted overwhelmingly to adopt the new name.

The meeting was opened by Ray E. Lawrence, WPCF President, who also spoke at the Awards Luncheon. The theme of the technical session was "Sanitation in the Sixties."

Papers given include the following:

"Casting Industrial Discharges in Proper Perspective—A Case History of the Pulp and Paper Industry of the Northwest," by Vinton Bacon, Executive Secretary, Northwest Pulp and Paper Association, Tacoma, Wash.

"Processing Industrial Wastes to Meet Changing Regulatory Standards," by Harvey Ludwig, President, Engineering Science, Inc., Arcadia, Calif.

"Sewage and Refuse—Related Wastes," by Robert D. Bargman, Assistant Director, Bureau of Sanitation, Board of Public Works, Los Angeles, Calif.

In addition to the technical sessions, concurrent schools were held on treatment plant operation and sewer maintenance. Breakfasts for different specialists were given to afford groups the opportunity to discuss matters of common concern.

Sydney Preen received the Bedell Award for outstanding service to the CWPCA. He is presently Superintendent of Sewer Maintenance for the City of Long Beach.

The William D. Hatfield Award was presented to William R. Teague, Manager of the Indio Sanitary District, for outstanding sewage treatment plant operation.

New officers are:

President: Elmer E. Ross, Oakland.
First Vice-President: Paul V. Hennessy, Laguna Beach.
Second Vice-President: Erman A. Pearson, Berkeley.
Secretary-Treasurer: Steven H. Goodman, Campbell.

STEVEN H. GOODMAN
Secretary-Treasurer

ARIZONA SEWAGE AND WATER WORKS ASSOCIATION

The Arizona Sewage and Water Works Association, Member Association of the Water Pollution Control Federation and the Arizona Section, AWWA, held their annual meeting on Apr. 20–22, 1961, at the Hotel Superstition Ho, near Phoenix.

A total registration of 296, consisting of members, non-members, and guests represented an increase of 5.7 per cent over the paid registration at last year's annual meeting.

Prior to the official opening of the meeting, an eighteen hole golf tournament was held on Thursday morning at the Apache Country Club. There were 48 enthusiastic participants. (They had to be enthusiastic to tee off at 6:30 AM.)

Ray E. Lawrence, President of the Water Pollution Control Federation, represented the Federation. R. J. Faust, Executive Secretary of AWWA, was also present. The opening luncheon included a welcoming address by Boyd H. Gibbons, Jr., Special Assistant to Governor Fannin for Industrial Development. Mr. Gibbons spoke on the remarkable rate of population growth in Arizona in recent years. He attributed this growth in the main to a tax structure favorable to industrial development, a desirable and healthy

(*Continued on page 709a*)

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climate, availability of skilled labor, a right to work law, and probably most important the trend of the newcomers toward a revival of the free enterprise system.

Ray Lawrence, the principal speaker at the Thursday luncheon, was formally introduced by E. O'Neal Dye, Director on the Federation Board of Control. Mr. Lawrence reviewed the accomplishments of the Federation and stressed what he termed a "milestone of progress" in the drafting and adopting of the 13 point Policy Statement on Water Pollution Control at the 33rd Annual Meeting in Philadelphia on Oct. 6, 1960. He stated that this statement has put forth the position and aim of the Federation for the first time. Mr. Lawrence also expressed himself as being pleased with the progress the Arizona Section has made in the voluntary certification of operators program. He stressed the value of the Operators Manual sections in the Federation Journal, in connection with this certification program.

Mr. Lawrence presented the William D. Hatfield Award for 1960 to E. O'Neal Dye, Superintendent, Tucson Sewage Treatment Plant, for his extraordinarily complete records concerning the Tucson Sewage Treatment Plant; and to Art F. Vondrick, Assistant Director of Water and Sewers, City of Phoenix, Mr. Lawrence presented the Arthur Sidney Bedell Award for 1960 for his outstanding work within the member association.

During the business meeting the Constitution and By-Laws of the Arizona Sewage and Water Works Association were amended and the name of the organization is now "Arizona Water and Pollution Control Association."

Following the bsuiness meeting there were sixteen ASWWA "Sewage Safety Awards of Merit" presented to various cities and towns for progress during 1960 in improving and/or initiating safety programs.

(*Continued on page 711a*)

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Papers of interest presented during the conference included:

"Selecting Sewer Pipe," by Don E. Bloodgood, Professor of Sanitary Engineering, Purdue University, Lafayette, Ind.

"Electro-Dialysis, Its Applications in Arizona," by Richard P. Fiedler, West Coast Manager, Ionics, Inc., Pasadena, Calif.

"New Concepts in Digester Sludge Mixing and Floating Covers," by G. E. Hauer, Manager, Municipal Sewage Department, Infilco, Tucson, Ariz.

"Metropolitan Approach to Sewage Collection and Treatment," by Paul Bolton, Henningson, Durham and Richardson, Consulting Engineers, Omaha, Nebr.

"Waste Control at Missile Facilities," by Ben Dibble, Vice-President, Johannessen and Girand, Consulting Engineers, Phoenix, Ariz.

"A Biological Study of the Sewage Lagoon of Sanitary District No. 1 of Pima County, Arizona," by Jack Hensley, Univ. of Arizona, Tucson, Ariz.

"Potential Application of Solar Energy in the Water and Sewage Fields," by Levi F. Yissar, Mechanical Engineer, President, Yis-Sol Products, Inc., Tucson, Ariz.

During the annual dinner dance on Friday evening, President R. E. Polenske installed the newly elected officers for the coming year.

The new officers of the Association are:

President: Stanford I. Roth, Phoenix.
First Vice-President: Milford E. Devine, Tucson.
Second Vice-President: Karl A. Hirlinger, Phoenix.
Secretary-Treasurer: A. D. Cox, Jr., Phoenix.
Director on the Board of Control: Art F. Vondrick, Jr., Phoenix.

A. D. Cox, Jr.
Secretary-Treasurer

(*Continued on page 713a*)

Personnel Service

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TEXAS WATER AND SEWAGE WORKS ASSOCIATION

The Texas Water and Sewage Works Association and the Industrial Water and Waste Conference met in College Station on Mar. 11–16, 1961.

The Texas Water and Sewage Works Association has approved a separation of the Sewage and Industrial Wastes Section and there will be two separate state associations.

Papers presented at this meeting include:

"Significance of Growth Rate in the Control and Operation of Bio-Oxidation Treatment Plants," by M. T. Garrett, Jr., City of Houston, Houston, Tex.

"Water and Waste Clarification," by Paul D. Haney, Black and Veatch, Consulting Engineers, Kansas City, Mo.

"Inhibitors in the Clarification Process," by Jesse M. Cohen, Chemist-in-Charge, Engineering Section, Research Branch, R. A. Taft Sanitary Engineering Center, U. S. Public Health Service, Cincinnati, Ohio.

Newly elected officers for the year 1961–62 are:

President: Claud K. Robinson, Vernon.
President-Elect: L. W. Smith, Temple.
Secretary: G. R. Herzik, Jr., Austin.
Treasurer: Mrs. Earl H. Goodwin, Austin.
Director: J. L. Robinson, Fort Worth.

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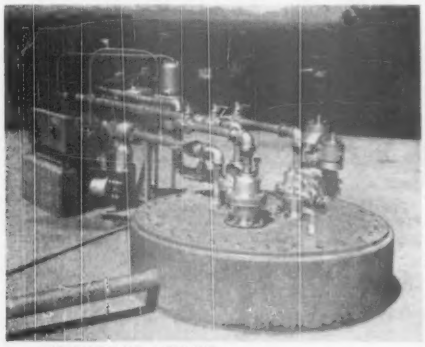

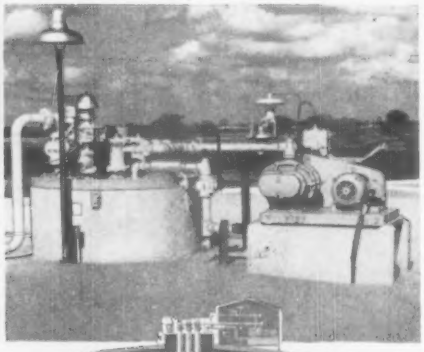

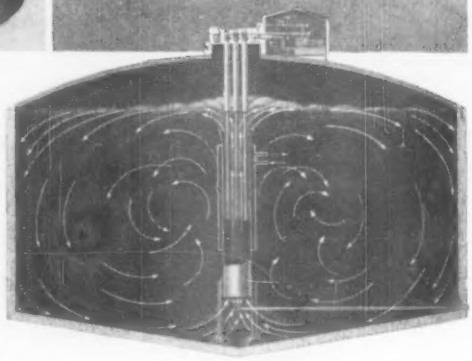

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Top right — SACRAMENTO COUNTY, CALIF. (San. Dist. #3) GASLIFTER in 70' dia. digester with fixed concrete cover. Mr. Norman Farnum, Supt. Dewante & Stowell, Sacramento, Cons. Engrs.

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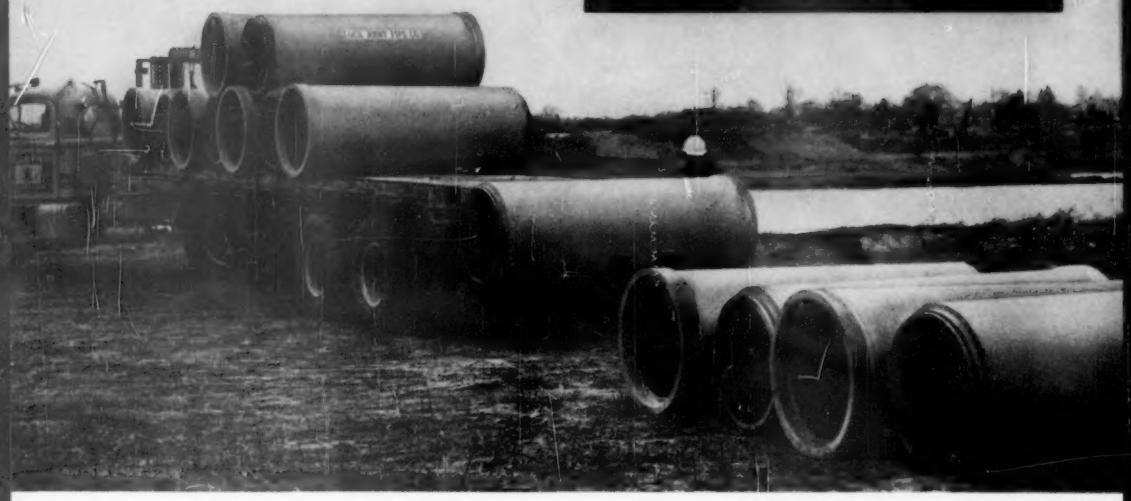

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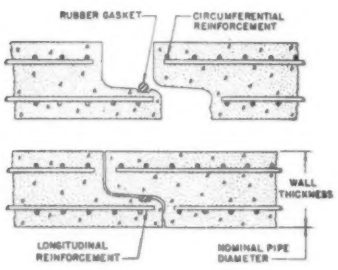

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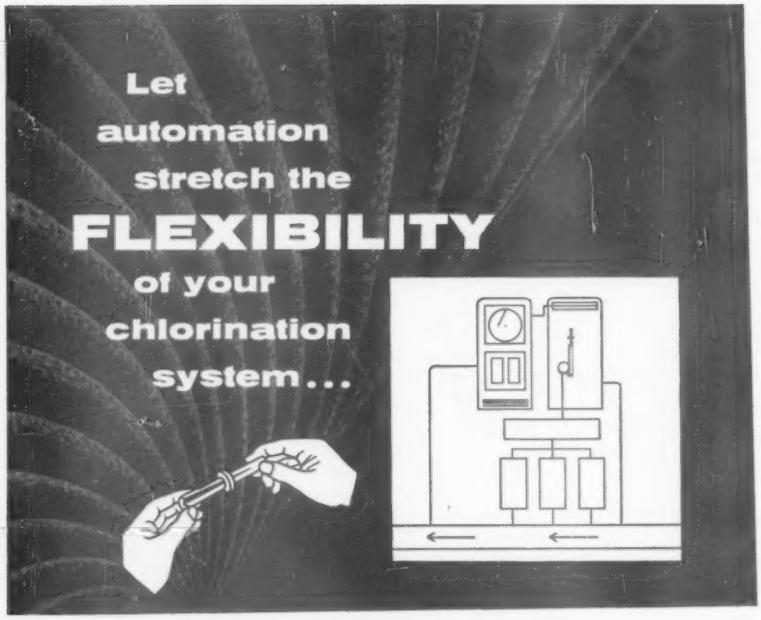

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